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MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. CIV.

EDITED BY

JAMES FORREST, ASSOC. INST. C.E., SECRETARY.

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CORRIGENDA.

Vol. ciii., p. 254, line 3, the No. should be "877" and not "8771."
" " " 6, *for* "609" *read* "600."
" p. 350, line 4, in the denominator of the fraction *for* "mile" *read* "mille."
" p. 496. Attention has been directed to the fact that the problems, with their solutions, contained in the abstract, "Self-Induction and Capacity," by P. Boucherot, were discussed and published by Mr. T. H. Blakesley, M. Inst. C.E., in 1885.
" p. 514, line 5, *for* "shape of the brick cylinders" *read* "shape of the cylinders."

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THE

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1890-91.—PART II.

SECT. I.—MINUTES OF PROCEEDINGS.

13 January, 1891.

SIR JOHN COODE, K.C.M.G., President,
in the Chair.

M. CARNOT, President of the French Republic, was elected by acclamation an Honorary Member.

It was announced that the following Associate Members had been transferred to the class of

Members.

HENRY RICHARD CARLETON, B.A., B.E.
HENRY JAMES COLES.
WILLIAM SANTO CRIMP.
WILLIAM CROSS (Newcastle-on-Tyne).
JOHN REGINALD HARDING.
GISBERT KAPP.
WILLIAM OLIVER EVELYN MEADE-KING.
EDMUND PENNY.

and that the following Candidates had been admitted as

Students.

GORDON ALLEN.
LEWIS BROWN BAGOT.
OSWALD BARKER.
FRANCIS EDWARD BENEST.
CHARLES MARCUS BLES, B.Sc.
JAMES LORD BOWNESS.
JOHN DU VALLON BRUNTON.
RALPH GEORGE CARTE.
JOHN ROBERT CHAMPION.
GEORGE FINDLATER CLEMENTS.
STAMFORD VAIR CLIREHUGH.
EDWARD FRANKLYN ELLIOT.
GEORGE GONSALVES.
EDWARD LONG GROVE.
HECTOR FREEMAN GULLAN.
CHARLES THOMPSON JOHNSON.
NAGENDRANATH MITRA.
REGINALD FREDERICK ERNEST RIDGWAY.
HENRY FRANCIS RUSSELL.
LEOPOLD HALLIDAY SAVILE.
ERNEST WILLMOTT SLOPER.
NORMAN MCLEOD RAMSAY WILSON.

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The Candidates balloted for and duly elected were as

An Honorary Member.

The Right Hon. LORD RAYLEIGH, M.A., D.Sc., F.R.S.

Members.

ANTONIO DE CARVALHO PAES DE ANDRADE.
WILLIAM BUCHANAN.
FREDERICK MARGARSON HYNES.
LOUIS JOHN MCKENZIE LOWE.

Associate Members.

DOUGLAS ALLPORT, Jun., Stud. Inst. C.E.
WILLIAM ARNOT.
EDWARD NEVILL BANKS.
CHARLES FREDERICK BECHER, B.A., B.E.
HORACE SAMUEL BOND.
HENRY JOHN BRIDGEWATER.
WILLIAM ALOYSIUS CASHMAN, B.E., Stud. Inst. C.E.
HENRY VINE CHAMPION.
NEVILLE BROOKES DAVIS, Stud. Inst. C.E.
HAROLD DEANS, B.A., Stud. Inst. C.E.
FRANK WILLIAM DODD, Wh.Sc.
ANDREW DUNCAN, Stud. Inst. C.E.
JOHN DUNN FERGUSON.
THOMAS FRAZER.
HENRY COLTHURST GODWIN.
WATKIN HALL.
HENRY JOHNSON.
SIDNEY COOKE LEWIS, Stud. Inst. C.E.
JOHN DA VINCI LOUCH.
ALFRED LUNN.
JAMES GILBERT STEVENSON MACINTYRE, Stud. Inst. C.E.
JAMES PORTER MAGINNIS.
PERCY EDWARD MITCHESON.
ROBERT EDWARD PEAKE.
ALFRED BARNES PICKARD.
DAVID PRICHARD.
LOUIS EDGAR ROBERTS.
WILLIAM CHARLES CLIFFORD SMITH.
FREDERICK CHENERY SUGGATE.
JOHN WULSTAN TWINBERROW, Stud. Inst. C.E.
EDWARD VENNING.

Associates.

THOMAS BLISSETT.
CAPTAIN JAMES DALLAS, R.E.

(*Paper No. 2490.*)

"Auxiliary Engines in connection with the Modern Marine Engine."

By WILLIAM HENRY ALLEN, Assoc. M. Inst. C.E.

ONE of the most striking features in the development of the marine engine has been the introduction of auxiliary engines. Formerly not only was the whole of the propelling power derived from one engine, but all the arrangements for dealing with the steam were concentrated in it; whereas in the present day the work is

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divided among a number of separate and highly specialized machines, each having its own definite function, upon the due performance of which depends the working of the whole.

The year 1840 marks an epoch in the history of the marine engine, when the inverted-beam, or side-lever, engine took substantial form. An interesting extract from a specification of that time reads: "Boilers to be proved by water-pressure to not less than 14½ lbs. at bottom of boiler, and shall be capable of generating sufficient steam at not less than 7 lbs. pressure to fill the cylinders for eighteen double strokes per minute with the passages open."

Then followed the oscillating and the horizontal engines, and these were the principal forms of marine engine in vogue up to the year 1860, both having low-pressure steam, scarcely ever reaching 50 lbs. per square inch. Later on the fact was recognized that high-pressure steam was more suitable and economical, and probably the Paper read before the Institution by Mr. Alfred Holt, in 1877,[1] had considerable influence on the minds of marine engineers. Since the before-mentioned date the overhead form of compound engine, with initial pressures of from 80 to 100 lbs. and expanding either in two or in three cylinders, has been adopted, and from about the year 1884 to the present time the triple-expansion engine has been the accepted form.

With higher pressures came the necessity for a surface-condenser, and thus began the separation of the condensing-plant and the introduction of circulating-engines. Now, most large main engines consist simply of the cylinder frame-work and ordinary working parts; the air-pump, circulating-pump, reversing-engine, feed-pump, and the turning-engines, being entirely separate from the main engines. The advantages which this arrangement possesses are manifest, as it would be almost impossible to construct large engines such as are now made, running at from 850 to 900 feet piston-speed per minute, and occupying such small compass, unless the condensing-power were separate.

Circulating-Pump Engine.

The earliest auxiliary introduced into the engine-room was the circulating-pump engine in combination with the surface-condenser. One of the first fleets of steamers on which this

[1] Minutes of Proceedings Inst. C.E., vol. li. p. 2.

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arrangement was adopted was that of the White Star Line, including the "Oceanic" and two sister ships, the former of which made her maiden voyage in 1871. Several difficulties occurred owing to makers of centrifugal-pumps advocating engines running at speeds which were not justified by experience. The result was that some of the earlier centrifugal-pumps had to be withdrawn and replaced by others containing larger disks for lower speeds. The mistake was probably due to the fact that the custom on land had been to work centrifugal-pumps by belts at an extremely high rate of speed, no direct-acting pumping-engines having then been properly designed, but as soon as it was recognized and corrected no further difficulty was experienced. When the "Arizona" was built in 1878, lower speeds and more suitable engines were adopted, and the auxiliary engines of this boat, after a period of twelve years, are still in good working order. The form of circulating-engine adopted for driving these pumps was in harmony with the design of the main engines, namely, the inverted cylinder, with cast-iron standard and columns, and this type has been used in all the largest steamers until it reached its maximum size when the "Umbria" and "Etruria" were built. The large circulating-pumps on board the "Umbria" and "Etruria" are shown in Plate 1, Fig. 1. They are 20 inches in diameter, and are each capable of discharging 9,000 gallons per minute at a speed of 110 revolutions, being driven direct by engines having cylinders 15 inches in diameter by 12 inches stroke, taking steam from the main boilers at 110 lbs. pressure and exhausting into condensers. The main engines indicate close upon 15,000 HP., requiring 1·2 gallon per indicated HP. when the engines are developing their full power. This may be taken as the fixed type of circulating-engine since 1884.

Subsequently, when steam-pressures were increased to 150 lbs. in triple-expansion engines, it was thought desirable that the circulating-pumps should have compound engines, to effect greater economy. The first large boats fitted on this principle with triple-expansion main engines were the "Aller," "Trave," and "Saale," of the North German Lloyd, the circulating-engines of which are shown in Fig. 2. These consist of two 16-inch pumps, each driven by twin engines having cylinders 8 inches and 16 inches in diameter by 10 inches stroke, capable of circulating water for condensing the steam of engines of 7,000 HP. at 120 revolutions. Each pump delivers at this speed 4,000 gallons per minute, which gives a quantity of about 1·1 gallon per indicated IIP. It will be readily seen that with

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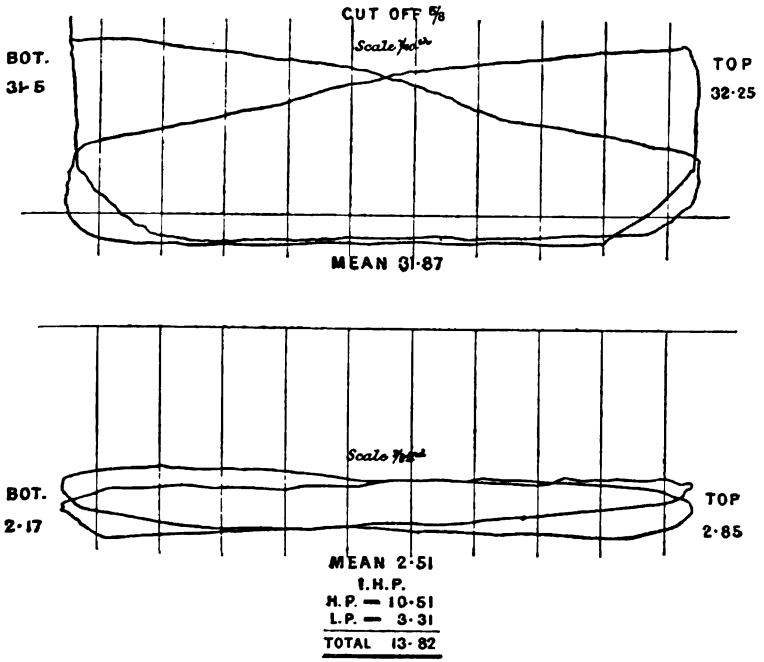
the full boiler-pressure of 150 lbs. the cylinders of these engines are far too large for the ordinary work of circulating; but in explanation of their capacity it should be pointed out that as it was usual to connect the centrifugal pumps with the bilge, it was necessary to make the engines not only sufficiently powerful for circulating, but also capable of working against a head equal to the depth of the bilge. For this reason the compound engines had to be designed for nearly three times the power which would otherwise have been sufficient. The diagram, *Fig. 1*, is taken from

Fig. 1.



INDICATOR DIAGRAMS OF CIRCULATING ENGINES, S.S. "ALLER." STEAM 150, VACUUM 28, REVOLUTIONS 130.

these engines, and it will be seen that the power required for circulating is only 13·82 indicated HP., whereas the engines are capable of indicating 90 HP. when dealing with the full capacity of the pump and total depth of bilge of 25 feet. This fact gave rise to the question as to whether a more efficient form of engine could not be devised, which would be large enough for bilge-purposes, and yet economical in its action when circulating. Accordingly the same form of engine which was used in the

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"Umbria" has been employed in the new Hamburg American steamer "Normannia," also the Castle Line "Dunnotar Castle," Fig. 3; but instead of using the steam from the boiler at a pressure of 160 lbs. for driving the circulating-engines, it is taken out of the high-pressure steam-receiver, and having done its work of circulating, is passed into the low-pressure steam-chest of the main engines. Thus a form of expansion has been obtained which is economical in the use of steam as well as in the first cost of the engine, while for the purpose of pumping the bilge, when the main engines are stopped, an auxiliary steam-pipe connects the engine with the main boilers.

The quantity of water generally used for circulating-purposes has of course decreased with the reduction of water evaporated per indicated HP. per hour. Thus, with from 25 to 30 lbs. per indicated HP. per hour the circulating-engines were required to give as much as 15 to 20 lbs. of water per minute for surface condensing, while with the triple-expansion engines, which use only 15 to 18 lbs. of water, the regular quantity seldom exceeds 10 lbs. It will be seen, therefore, that the "Arizona," indicating 6,000 HP., required 13 lbs. of cooling water per HP. per minute; the "Umbria," of 15,000 HP., built in 1884, 12 lbs.; and the "Aller" class, built in 1886, triple-expansion, indicating 7,000 HP., required 11¼ lbs.; and in the "Normannia," built in 1889, there are two engines indicating 13,000 HP. which use about the same quantity. It is found that the quantity of condensing-water is a matter of some consideration, as a difference in temperature above or below the normal point is detrimental to good working. Should the surface not be enough, or the condensing water be insufficient in quantity, then the vacuum obtained will be lower than that desired; whereas, on the other hand, if the circulating pumps deliver too much water the condensed steam is reduced to a temperature below that at which it is economical to return it to the boiler.

So far as the Author knows, no experiments have been carried out on the condensing-plant of marine engines, and consequently the data for regulating the size of the machine must be those obtained from practice. The Author has found the friction of the condenser-tubes, together with the velocity of entrance, as well as the friction of the circulating-pipes themselves, to be equivalent to a head of from 5 to 10 feet; that is to say, that in calculating from the speed of the centrifugal pump, as well as the quantity of water known to be delivered at this speed, from 5 to 10 feet is the range of pressure against which it is necessary to work.

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Comparing the quantity of water discharged with the indicated HP., the efficiency at this head, and with the moderate number of revolutions at which they are operated, has been found to be 50 per cent. This result was with a velocity of water of from 9 to 10 feet per second through the circulating-pipes, which accords with the common practice in the merchant service. In the Navy much higher velocities have been used, in some instances 15 feet per second, but the effect of this must be to considerably diminish the duty of the centrifugal-pump. The above efficiency must be considered fairly good when the large range of power for which the engines are constructed is taken into consideration.

Safety of working in this department of a twin-screw marine engine is in a large measure assured by cross-connecting the circulating-pumps, so that in case of emergency either of them could be employed for condensing the steam from both engines. This method, which has been recently carried out in the new mail boats "Empress of India" and two sister vessels for the Canadian Pacific Railway Company, is shown in Plate 1, Figs. 4 and 6. In this ship, which is divided by a longitudinal bulkhead in the usual way, the circulating-pumps are attached to both condensers by cross-connecting with a system of valves. Each pump is provided with two engines, either of them being powerful enough to supply its own condenser, and the two together capable of working the pump at a sufficiently accelerated speed to provide water for both condensers. This method has also the advantage of keeping down the area of the cylinders for circulating, while still retaining full power for bilging.

The Author recommends that for steamers having horse-powers ranging from 6,000 upwards, the speed of the centrifugal-pumps for circulating-purposes should not be less than 150 revolutions per minute, a lower speed only adding to the weight and bulk without having any advantage. In some instances the Author has noticed that the main engines, with strokes of 5 or 6 feet, have been travelling at a higher number of revolutions than the comparatively small centrifugal pumping-engines, with strokes of only 10 to 12 inches, which is an evident anomaly. As it is quite possible to make such engines work with certainty at 150 or 180 revolutions per minute, there can be no reason why the above-mentioned speed should not be adopted. These remarks apply only to the Mercantile Marine, for in the Navy the question is somewhat different; there the engines are only required to develop their maximum power on trial trip or on special occasions, and the pumps can then be readily worked up to 250 to 300 revolutions

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per minute; while the normal speeds, when the engines are only indicating half power, will fall under 200 revolutions.

The custom of duplicating auxiliary engines seems now to have entirely fallen into disuse, past experience having proved it to be a totally unnecessary practice, not only increasing the first cost, but necessitating the carrying of so much dead weight to no purpose. If the circulating-engines are well made, there is no more occasion to duplicate them than the main engines.

Probably no better instance can be given of the regular running of ships with single circulating-pumps, than that of the New Zealand Steamship Company's fleet of the "Tongariro" class, 4,500 HP., fitted with single 15-inch pumping-engines in 1883, Fig. 5. These vessels have been running ever since without any break-down or stoppage.

There has been considerable difference of opinion as to whether centrifugal pumps should be made entirely of gun-metal, or of cast-iron, or with cast-iron casing and gun-metal disk. The Author's experience with cast-iron disks and casings is entirely in their favour, as, in many cases which have come under his observation, the pumps have shown no sign of corrosion after being at work for fifteen years. On the other hand, centrifugal-pumps made with gun-metal disks and cast-iron casings, have shown considerable pitting in the latter, after being at work for a few years, no doubt from galvanic action set up by the contact of the salt water with the two different metals.

In connection with centrifugal-pumps several instances have come under the Author's notice where circulating-pumps have given considerable trouble through a reduction in the area of the suction-pipes, valves, and gratings. As a centrifugal-pump, in order to work with advantage, should have its full area of pipe kept open all through the system, it becomes necessary that the inlet should in every case be quite free, and that nothing should be allowed to enter the pipes which would be likely to choke the passage, such as seaweed or other matter. This has frequently occurred through neglect, and too much care cannot be taken to prevent it.

Separate Air-Pump Engines.

The practice of entirely disconnecting the air- and feed-pumps from the main engines, and working them by their own steam cylinders, has not been universally adopted, but there are several

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instances of such separate sets of engines giving great satisfaction. A diagram of one of these is shown in Fig. 7. In it the air-pumps are below, and are worked direct from the cross-heads, the steam-cylinder being inverted. On either side are placed feed- bilge- and sanitary pumps, the machine being thus thoroughly balanced in all its movements. A crank-shaft is employed, having ordinary connecting-rods, with flywheels at each end, so that the motion is tolerably steady. One of the best examples of this kind of work is to be found in the s.s. "Normannia" of the Hamburg-American line. In this case the cylinders are not triple-expansion, but receive their steam from the high-pressure steam-chest of the main engines, and exhaust into the low-pressure steam-chest of the same, thus using the steam expansively and without much loss. The arrangement shown is extremely compact in itself, and the system is very convenient in engine-rooms provided with twin engines, where space is limited, and there is not room for the air-pumps to work in the ordinary way.

The advantage which this class of auxiliary engines possesses consists in the fact that the pumps can always be started before the main engines, and thus by the use of separate centrifugal-pumps in addition, a vacuum can be produced ready for the first stroke of the main engine. This method has also been employed where new engines of larger size have been introduced into old boats, in which lack of space has compelled the designers to seek some other way of working the air-pumps than by having them connected with the main engines, as, for instance, in the London and North Western Railway Company's boats "Lily," and "Violet."

Auxiliary Combined Pumping-Engines.

For creating a vacuum in the auxiliary condenser, the combined air-pump and centrifugal-pump, shown in Fig. 8, is a useful appendage in the marine engine-room. By increasing the diameter of the disk of the centrifugal-pump, the revolutions can be reduced so that the air-pump can be made to run without any difficulty. The maximum speed for which these pumps have been made to run is 250 revolutions per minute.

Fans for Forced Draught.

The keen competition which now exists among steamship companies, and the consequent demand for higher speeds, has

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made it almost a necessity to employ artificial draught in order to provide sufficient air to burn the required quantity of coal on a reduced grate-area. A trial of induced draught by jet-nozzles not having met with the success which was anticipated, the method seems now to have been more or less discarded. The different methods of applying forced draught which have come under the Author's notice are the closed ashpit system with cold air, the closed ashpit system with hot air, the air being passed through tubes in the smoke-box, the closed stoke-hold system, as universally employed in the Navy, and the open stoke-hold system, in which the fans are employed for assisting the draught. In all cases the centrifugal-fan appears the best means of providing the necessary air-pressure.

The Author believes that the first application of fans for forced draught was made by the late Mr. Thornycroft, on one of the early experiments with fast-running boats. During the last eight years the adoption of fans in mail steamers and in the Navy, has gradually become universal, the Author alone having fitted as many as six hundred sets during the last five years. The first fleet of steamers of any size in constant service fitted with fans was the City of Dublin Mail Steam Packet Company's line, running between Holyhead and Dublin; forced draught was introduced on these in 1883, and it has since been applied to each of the Company's steamers, eight fans being placed in the first and each succeeding vessel. The use of these machines has led to the shortening of the passage by at least half an hour, and has in every way rendered steaming more easy.

The success of this work gave an impetus to forced draught in coasting steamers, and it has been applied in nearly every instance to new passenger vessels, as well as to a number of old vessels at present working round the coast. The several fleets of steamers which have been fitted by the Author with direct-acting fans during the last six years are as follows:—The boats running between Belfast and Glasgow, the Liverpool and Isle of Man boats (4), Liverpool and Llandudno (2), Holyhead and Dublin (4), City of Dublin Steam Packet Company's (5), London and North Western new steamers (2), Great Western boats, running between Weymouth and the Channel Islands (3), Brighton and South Coast boats running between Newhaven and Dieppe (2), Chatham and Dover boats running between Dover and Calais (3), and the Netherlands Steamship Company's boats running between Queenborough and Flushing (4). From this list it will be seen that all the principal lines of passenger steamers running from

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England to neighbouring shores have been fitted with fans for forced draught.

Fig. 10 shows the form of fan and engine supplied to the City of Dublin Steam Packet Company's boat "Ireland," there being four fans of a diameter of 7 feet 6 inches, each capable of delivering 50,000 cubic feet of air per minute for a HP. of 6,000.

Fig. 11 represents eight sets of 7-foot fans driven direct, as fitted on the passenger steamer "Mona's Isle," for the Isle of Man service, each set of which is capable of delivering 40,000 cubic feet of air per minute.

The above refer to coasting or channel steamers only. Forced draught, however, has by no means been confined to coasting steamers, as recently all the Atlantic liners, as well as some boats trading to Australia, have been equipped with assisted-draught fans of various kinds.

Fig. 12 shows the form of fans employed in the China line of steamers of 3,000 HP. They were made of rather large diameter, for giving only light pressures in the stoke-hold, so that they might run from Liverpool to China without stopping, and without fear of accident. They are 6 feet 6 inches in diameter, and are capable of delivering 20,000 cubic feet of air per minute, and fitted with tandem engines, having cylinders 7 inches and 12 inches diameter, by 7 inches stroke. They have been at work for the last six years, and the owners are adding duplicate sets to their new fleet. A convenient method of fixing fan-engines to bulkheads is shown in Fig. 9, being one of five in the p.s. "Adder."

The application of fans, however, may have a twofold purpose, namely, to enable more coal to be burnt in a given time, and also to reduce the temperature of the stoke-hold, which is always a desirable object.

Fig. 13 shows a set of fans which have recently been placed by the Author on the "Majestic" and the "Teutonic" for this purpose, and have been the means of considerably increasing the speed of these vessels. They are above deck, and are used for providing air for the forced draught below. They are 7 feet 6 inches in diameter, and each is capable of delivering about 50,000 cubic feet, making in all 200,000 cubic feet of air delivered per minute in each vessel. The fans are driven by engines having cylinders 6½ inches and 13 inches diameter, by 8 inches stroke, with 180 lbs. of steam taken direct from the boiler. They run at 250 revolutions per minute, and work steadily without vibration. The last and probably most important example

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of the introduction of forced draught into the Atlantic steamers, is that of the s.s. "Normannia," 13,000 HP., the stoke-holds of which are provided with twelve sets of single inlet fans, each driven by a tandem compound engine of economical form. When it is considered that the weight of these twelve fans is only 6 tons, and the advantages obtained by the reduction in the weight of the boilers are taken into account, as well as the accelerated speed, it will be seen how great a benefit arises from the introduction of forced draught when used for moderate pressures. At present there is no general consensus of opinion on the subject of forced draught, and it would appear that every system requires a different quantity of air and a different pressure; but as regards quantity, it is safe to take as a liberal allowance 260 cubic feet of air per lb. of coal, although, considering the waste there is sometimes in leakage, and through outlets where the air will probably find vent instead of through the fire, it may be prudent, under some circumstances, to add considerably to this amount. As an example of the different conditions which may be met with, it may be stated that on one vessel of 8,000 HP., the Author fitted fans capable of delivering 200,000 cubic feet of air per minute, and in another, indicating 13,000 HP., the fans provided 130,000 cubic feet per minute only, with equally good result.

At present the pressures for forced draught vary from $\frac{1}{2}$ inch of water upwards, according to the system, but, until further progress is made in high-pressure boilers, the Author is of opinion that a pressure exceeding $\frac{3}{4}$ inch of water in the ashpit is not advisable, involving, as it does, leakage in the tubes, and other troubles. Experiments, both in England and abroad, show that the large variation in the quantity of air required in the different systems makes it almost impossible to give any proper rule. An instance of this may be found in the introduction of forced draught in the Queenborough and Flushing boats, the fans supplied to the last few steamers being 18 inches less in diameter than the earlier ones, with equally good results. It may be observed that these fans are employed only for assisted draught. Considerable benefit, however, has been obtained with even these small fans, particularly when the wind is abaft the funnel, as it is then that the stokers find the greatest difficulty in maintaining their pressure. The same may be said about the steamers which travel in the trade-winds, many of which are being supplied with fans for providing air when going with the wind.

All the fans above mentioned are driven direct from their own engines, and are under the control of the engineer. Belt-

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driven fans are not suitable for steamship purposes, it being impossible to work a high-speed belt properly when it is placed longitudinally with the ship, which is generally the most convenient arrangement. This, together with the proximity of dust and grease, renders the system an unsafe one. Seeing how readily engines and fans combined can be fitted into any corner, it is evident that direct driving is the best.

There now is no difficulty in making large fans to run true within $\frac{1}{16}$ inch in their diameter as well as sideways, for sizes up to 7 feet or 8 feet diameter. Considerable reduction has also been effected in the weight. The first large fans, constructed by the Author in 1885, were 7 feet 6 inches in diameter, and weighed 28 cwt. each. By improvements in the construction, the present form, which is capable of working at higher speeds, and against heavier pressures, weighs only 16 cwt. This decrease in weight is not only a gain in itself, but assists greatly in keeping down vibration.

All fans for high-speed engines should be bolted down to a substantial foundation. To bolt a high-speed fan against a thin plate bulkhead without supports will, in a great measure, tend to increase vibration, and will possibly fracture the base-plate. Experiments on this subject clearly show that solidity of foundation is essential for engines of this class.

It having been suggested by leading authorities that a central diaphragm would add considerably to the efficiency of the fan, the Author carried out a series of experiments on the subject, and satisfied himself that no benefit accrued from its introduction. It would at first sight appear that the two currents of air meeting in the centre would tend to destroy each other in a measure, but the trials proved that bosses having curved entrances to about the diameter of the inlet were in every way as efficient as if the diaphragm had been carried right through.

The speed of fans depends upon their diameter and the amount and pressure of air required, but as it is limited by the maximum rate at which quick-running engines can be driven without excessive wear and tear, a speed of from 250 to 350 revolutions per minute may be regarded as the safest and most satisfactory for engines running on long voyages. The efficiency of the combined fan and engine is not high, the maximum obtained by the Author in experiments on fans of from 4 feet 6 inches to 6 feet in diameter suitable for steamship purposes, being only 42 per cent. As, however, the power required for driving fans on large ships is but a small proportion of the whole, it is highly desirable to keep up the areas of the cylinders, so that, in the event of the

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steam-pressure dropping, they may be sufficiently large to maintain the full speed required by the fan until it is restored. For calculating the areas of the cylinders an efficiency of 35 per cent. would ensure the engines being of ample power.

With regard to the velocity of the air, a good practice in calculating the diameter of fans is to allow from 40 to 50 feet per second in the suction-orifice, when working at the speed mentioned above. This would permit a considerable margin in the capacity of the fan in case it should be required to give a large volume or a higher pressure at any time.

The arrangement of the pipes leading from the fan to the closed ash-pit is of great importance. In several ships to which fans made by the Author have been fitted on board by the builders, the whole of the pipes had to be removed when the trials were made, no pressure being obtained in the ash-pit, although a water-gauge indicated 4 inches at the fan. This was entirely absorbed by friction, for it must be remembered that the pressures are at all times light, and will take very little to annul them. The pipes should be of ample diameter and the bends should be made with easy curves, all angles and Z-pieces being avoided.

The value of fans on board ships can only be appreciated by those who have gone to sea with and without them. When used for forced draught not only are the owners benefited by a result in many cases exceeding their expectations, but the comfort of the stokers is increased. If owners were to consider this more they would soon be convinced of the advantage of attending to the comfort and well-being of those engaged in the engineering department.

The Author infers from questions put to a number of engineers that general opinion is in favour of the use of the fan, which has now rendered it easy to maintain the steam-pressure, and has put an end to the constant pricking and slicing which tended more than anything to knock up the stokers.

Reversing-Engines.

At about the same time as centrifugal pumps were introduced, the auxiliary engine employed for the purpose of operating the reversing-links of the main engines came into use. The form which was usually employed at first, and which is now common in small steamers, is that known as the "roundabout" engine (Fig. 15). It consists of an ordinary reciprocating engine having

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a cylinder of from 5 inches to 8 inches diameter, working the ordinary wheel motion. The crank on the second shaft is connected either to the weigh-shaft of the main engines, or to the links themselves, and arranged so that the links may be reversed ahead and astern. The reversing action takes place by turning the steam into exhaust by the ordinary central valve. For engines up to 1,500 indicated HP. where there is plenty of room, this arrangement answers the purpose well. Some engineers also prefer this plan on account of its being very suitable for heating up the main cylinders before leaving port by starting the reversing-engine at slow movement, when it will admit a small volume of steam on both sides of the main piston, by the fact of the reversing engine bringing the links backwards and forwards from ahead to astern; also the engineer can leave the engine working in perfect safety, which cannot be done so well by any other system. While this form has generally been adopted for small engines, it has been almost entirely superseded in large engines during the last ten years by one in which the action is direct. This is known as the hydraulic reversing-engine, and is shown in Fig. 14. It consists of a steam-cylinder, the movement of the piston of which is controlled by a hydraulic oil-cylinder. This gives an exceedingly smooth motion to the weigh-shaft, and renders the engines capable of being controlled with ease, and what is often of great importance in an emergency, it is also much quicker in its action than the roundabout gear. Fig. 14 shows the reversing-engine as applied to the Pacific mail steamers "Orizaba," "Oroya," "Oruba" and "Oritava"; it is bolted direct on to the back column of the main engine, the handle for operating the steam- and oil-valves being carried to the platform at the front. These reversing-engines are always fitted with automatic cut-off gear, which renders their adoption a matter of considerable convenience for the engineer in charge; for the movement of the small hand-lever which controls the steam-valve is followed by the motion of the reversing-engine only so far as is necessary, the automatic gear cutting off the steam and oil at the required position, so that when the engineer is called upon either to put his engine to full speed ahead, or half speed astern, or any other point, he knows that the links of the main engine will correspond to the position in which he places the handle. The automatic cut-off controlling-gear consists of a set of differential wheels and levers which are positive in action; they are either connected to the weigh-shaft or to the cross-head of the reversing-engine, and by links and levers to the valves on the reversing-engine. The operation of altering or reversing the position

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of the links having been accomplished, the hydraulic cylinder takes upon itself the function of a locking gear, its valve preventing oil from passing from one side to the other, and so securing the piston in the required position. The action known as thrusting of the link-blocks is greatly lessened by the solid way in which the oil cylinder acts upon them. The hydraulic cylinder having a tail-end piston-rod has consequently the same capacity at each end, and the only leakage therefrom, which would be from the gland, is made up by the accumulator, Fig. 14. This accumulator is in connection with the hand feed-pump, which is a necessary adjunct to the reversing-engine, in order that the engines may be reversed by hydraulic power as well as by steam, as explained hereafter. It consists of a small cylinder with leathern piston pressed by a steel spring, the piston-rod passing through the top of the cylinder, and thus forming an index to its position inside. When any leakage occurs in the oil-cylinder of the reversing-engine, the piston of the accumulator follows the leakage and so keeps up the same pressure throughout the whole system. The fact is immediately made known to the engineer in charge by the piston-rod of the accumulator, which is visible, having fallen, and it is at once made good by a few strokes of the hand-pump. Hence, if the hydraulic cylinder is properly looked after, the reversing-engine can be regarded with confidence as a means also of holding the links firmly in position when the engines are worked at full speed.

This engine can be readily used for reversing the main engines by hand, with the small hydraulic hand-pump connected with it. While steam is down the hydraulic gear can be used to reverse the main engines, as is often necessary when in port, thus making the arrangement very complete. The diagram Fig. 14 shows the reversing-engines of the Royal Mail paddle-steamer "Ireland," sailing between Holyhead and Dublin. Some idea of the power of these engines will be gained from the size of this reversing-engine, the steam-cylinder of which has a diameter of 32½ inches, with a stroke of 43½ inches, the operating piston-rod being as much as 4 inches in diameter. The motion of the reversing-engine is generally communicated to the weigh-shaft of the main engines by side rods, which can be arranged in the ordinary way, or with a slot-link between the hydraulic cylinder and the steam-cylinder.

Small reversing-engines are now being generally used in river-tugs. The difference between the work of reversing the main engines by hand and that of actuating the starting-valve of the

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reversing-engine is thoroughly understood by those in charge of such craft.

It is somewhat difficult to indicate a rule for determining the size of starting-engines, owing to the power required for reversing the main engines varying with the system of valves employed, piston-valves taking considerably less power to reverse than ordinary slide-valves; but to enable comparisons to be made it may be mentioned that for compound engines indicating 6,000 HP., with steam-pressures of 100 lbs., the Author has fitted starting-engines with cylinders 20 inches diameter by 24 inches stroke, the main engines in this instance having piston-valves in the high-pressure cylinder, and D-valves in the low-pressure cylinder. For engines of 7,000 HP. of the triple expansion type, having piston-valves for the high-pressure and intermediate cylinders and D-valves for the low-pressure cylinder, reversing-engines are provided having cylinders 20 inches diameter by 33 inches stroke. For engines of smaller power, say 5,000 HP., reversing-engines having cylinders 14 inches diameter by 20 inches stroke have sufficed. It is well, however, to have them larger than is actually required when working with the full boiler-pressure, as it is important that they should be sufficiently powerful to reverse the engines in port when only the donkey-boiler may be at work with a pressure of 80 lbs.

A further extension of the use of this form of steam and hydraulic power has been made in the engine-room since the introduction of high-pressure steam. Instead of employing the ordinary screws for lifting the valves on the main steam-pipes, this is done by small steam- and hydraulic-gear placed on the steam stop-valve, or connected therewith from any part of the engine-room by the necessary levers, rendering the work of opening this large valve exceedingly easy.

Electric-Light Engines and Dynamos.

These are among the latest additions to the engines placed under the care of the sea-going engineer, but they have come into use so rapidly that it is now the regular practice to fit up cargo-steamers as well as passenger-steamers with electric light. The difference in the comfort of a ship going to sea with electric light on board as compared with the use of oil-lamps can only be judged by those who have had experience with both. A paper on this subject was read before the Institution by Mr. Jamieson in

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1884,[1] since which time considerable advances have been made in perfecting the dynamo and engine for ship work. In the interim, nearly every variety of engine has been tried—turbine, three-cylinder, rotary, single- and double-acting, open and closed, high and low speed; but the general opinion appears to be that the double-acting engine, specially constructed for driving dynamos, is the form which, in the future, will find the most favour for marine work.

At present electric-light machinery may be classed under two heads—namely, that specially suitable for Admiralty purposes, the highest economy and efficiency being the principal points in the specification, and that appropriate for ordinary merchant steamers, where a good sound practical engine and dynamo are looked for before economy, except probably in the best Atlantic liners, where compound engines of economical form may be found.

The question as to whether dynamos should be driven direct from engines or by rope-gearing has, the Author thinks, been settled by the general adoption of the direct-working machine; and, when it is considered how desirable it is to dispense with any belting or gearing, where, as on board ship, oil, grease and water are sure to be present, the advantages of direct-driving become apparent.

The engine used for Admiralty work is shown in Fig. 16, from which it will be seen that it is of the compound form with twin engines. This form was constructed by the Author in 1885, and a drawing of the same was exhibited with Mr. Kapp's paper on dynamos.[2] The twin form is equally advantageous both for high and low pressures, and single or compound engines, the effect being for one engine to entirely balance the other, which at high speeds is most essential. As an instance of the endurance of engines of this class, the Author may point to three sets of his dynamos and engines fitted on H.M.S. "Devastation" in 1884; which have been working constantly and regularly without stoppage, except when they have been changed over, at 300 revolutions per minute, with the full voltage and current. On the dismantling of this ship recently, in order to introduce triple-expansion engines, the dynamos and engines were transferred, with an ordinary overhaul, to another vessel of low steam-pressure, and this after six years of hard and continuous work.

The speed of Admiralty engines for electric lighting is now

[1] Minutes of Proceedings Inst. C.E., vol. lxxix. p. 1.
[2] *Ibid.*, vol. lxxxiii. p. 154.

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fixed at 320 revolutions per minute. The diagram represents a dynamo capable of giving off 400 amperes at the regulation pressure of 80 volts when running at 320 revolutions, the engine having cylinders 8 inches and 14 inches diameter by 8 inches stroke.

The Admiralty basis for testing engines of this class is a steam-pressure of 100 lbs. per square inch, exhaust being made into the atmosphere, and at this pressure in engines made by the Author the consumption of water is 33·7 lbs. per HP. hour of output at the terminals of the machine. This form of engine and dynamo is a considerable improvement upon the earlier types. Until 1888 the quantity of water generally taken with open engines was as much as from 40 to 42 lbs. per electrical HP. hour.

Probably the British Admiralty has had more experience in dynamo-driving for steamships than any foreign government or private firm. Beginning many years ago with alternate-current machines driven by belt off the capstan, the high speeds of dynamos were brought down until they overlapped those of the engines. Some of the latter were tried at first at 800 revolutions per minute, of the three cylinder and rotary form; then the speed was gradually reduced to 250 revolutions for double-acting, and 350 to 400 for single-acting engines, until finally, at the present time, the question is settled in favour of the twin double-acting engine running at a speed of 320 revolutions per minute.

The Author is of opinion that progress has been largely accelerated by the close specifications issued by the Admiralty, without which latent ability would not have been developed and such great improvements effected in so short a time. The economy of engines and dynamos has been improved both by increasing the efficiency of the dynamo and by reducing the quantity of water required by the engine itself. Naturally, with a higher pressure of steam, combined with the use of the condenser, considerable reduction can be made on the above figure of 33 lbs.; but it will be readily understood that as all engines are tested at Portsmouth on the lines specified above, a comparison can only be properly made under those conditions. It will also be seen that these engines have in themselves certain qualifications which give them an advantage over closed engines, namely, accessibility, simplicity, and economy, combined with the all-important one of durability. It must not be forgotten too that the twin engine with cranks at opposite angles—such as is exclusively used at the Admiralty—has the advantage of working with considerably less vibration than the single-cylinder engine.

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For the mercantile marine, however, an altogether different class of engine seems to be required. With the exception of some of the largest liners, nearly all vessels are now being fitted with single-cylinder direct-acting engines and dynamos, the object of the owners being to secure a machine which will run constantly without repair or breakdown, and one which can be readily understood by ordinary marine engineers, and repaired by them when necessary.

The type of engine and dynamo usual in the mercantile marine is shown in Fig. 17. The engine is of the inverted single-cylinder form connected direct to the dynamo without belting, and the whole is so constructed that any part can readily be removed. The essential features of this class of engine are:—working parts balanced as far as possible—low pressures on the bearings, obtained by large surfaces—and accurate workmanship.

It may be mentioned that the practice for merchant vessels has hitherto been to work engines of this class at a speed probably higher than experience would justify. The Author is of opinion that for engines capable of lighting boats requiring 200 to 400 lights, a speed of 270 revolutions per minute is one which can be maintained and relied upon without danger of breakdown, and at the same time it admits of a fair size being given to the engine and dynamo without excessive weight and space being occupied.

Governor.

One of the most useful additions lately made to direct-acting sea-going dynamos is that of the fly-wheel governor. Until this improvement was effected it was necessary as a rule to watch the engine and dynamo in order to regulate its speed. It is absolutely necessary for marine work that the governor should be driven from the engine without the use of belting, as it seems impossible to keep belting from slipping, owing to the unavoidable splashing of oil and water. The usual practice when this occurs has been to take the belt off the governor, and work the engine without it, a man standing by the stop-valve to regulate the voltage from time to time. This is now obviated by the improvements which have been made in direct-acting governors. The Admiralty specifications require that the speed shall be capable of regulation by hand while the engine is running, for which purpose the fly-wheel governor is inapplicable, and the ordinary ball and spring form

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is generally employed, provided with hand-regulation. It is a further condition in the Admiralty specifications, that the momentary increase of speed and voltage, when the whole load is instantaneously thrown off, should not exceed 25 per cent. of the normal.

For all ordinary purposes of merchant steamers, however, these conditions are not necessary, and a governor which will maintain a steady voltage independent of the steam-pressure, and the current given out by the dynamo, is one which finds most favour. The fly-wheel governor holds the eccentric in suspension, and regulates the stroke of the steam-distribution valve in accordance with the work given out by the machine, and in the event of the full load being suddenly thrown off, prevents the speed of the engine from being increased more than 3 per cent.

Dynamos.

The ship-lighting dynamo has been greatly improved of late, and the drum-wound armature machine, Fig. 16, is one which has been found to work satisfactorily. The armature consists of a cast-iron hub mounted on a steel spindle, having laminated plates for the core, the whole being drum-wound on the outside. Every part at all likely to get out of order is visible, and can be readily repaired by those who have charge of the machine.

The voltage at which the Author has found it most convenient to work in merchant ships is 60 volts, which is suitable for glow-lamps as well as for projectors.

It will be borne in mind that most of the auxiliary engines placed on the lower platform have to work in temperatures varying from 90° to 120°, and hence it becomes necessary that the dynamo used for shipwork should heat as little as possible above such a normal temperature. The Author's experience is that dynamos can be readily made with the cooling surface, and the rate of development of heat so proportioned that neither armature nor field magnet rise more than 50° Fahrenheit beyond the temperature of the surrounding air after a run of six or seven hours. At the above temperature, therefore, there can be no difficulty in making engines and dynamos to fulfil their duties in as efficient a way as any of the other machinery in the engine-room.

Bearing in mind that the electric-light engine has generally to work harder and longer than any other in the ship, the light being required both when in port and when at sea, the matter of

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economy is of some importance. This will no doubt have further consideration at the hands of shipowners. The efficiency of ordinary ship-lighting dynamos, with double-acting engines, is considerable, reaching in some cases as high as 83 per cent. It will be observed from the Table in the Appendix that the efficiency of dynamos of the ordinary mercantile form is over 81 per cent. This result has been obtained from a number of machines of similar size. The curve, Fig. 2, shows the efficiency of engine and dynamo combined, from no load to full load.

The above description of auxiliary engines does not by any means exhaust the list of those which are to be found in the marine engine-room of the present day, as mention should be made of the present form of feed-pump, which is generally of the duplex pattern, without fly-wheel; also the evaporator with Weir's hot-water feed-pump; the refrigerating-apparatus, which has generally the horizontal compound engine, with air-pumps opposite to the same; the steering-gear which is sometimes placed in the engine-room; the small engine for turning the engines round when in port; the distilling-machinery; the air-compressors, when the cabins are ventilated by nozzles; and the ash-hoists. The Paper has, however, extended so far that it would be impossible to embody all the details of these engines, and the Author has therefore preferred to confine himself to the four classes which have come within his own experience.

The Paper is accompanied by drawings, from which Plate 1 and *Figs. 1* and 2 have been prepared.

[Appendix.

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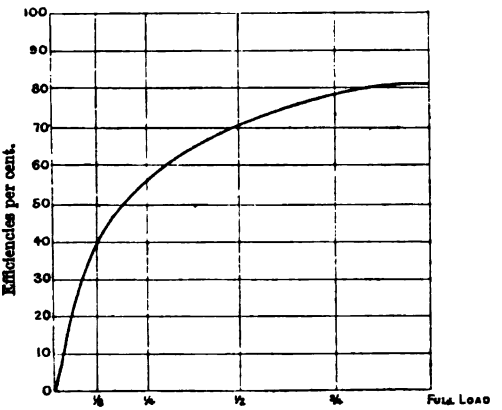
APPENDIX.

COMBINED EFFICIENCY OF ENGINE AND DYNAMO.

Proportion of Full Load.	Loss in Engine, Dynamo-shaft and Bearings.	Loss in Dynamo.	Losses in Engine and Dynamo combined.	Output.		E.HP.	I.HP.	Combined Efficiency.
				Volts.	Amp.			
Engine with dynamo unexcited	5·5							
Engine with dynamo excited .	5·5	3·79	9·29	81·0				
Per Cent. 12·8	5·5	3·80	9·30	80·00	55	5·89	15·19	Per Cent. 39·0
24·5	5·5	3·85	9·35	82·50	102	11·25	20·60	54·5
48·5	5·5	4·02	9·52	82·50	203	22·40	31·92	70·0
72·0	5·5	4·57	10·07	80·50	306	33·10	43·77	76·5
100·0	5·5	5·36	10·87	80·25	429	46·10	56·97	81·2

Losses expressed in HP.

Fig. 2.



Curve showing efficiency of Combined Engine and Dynamo.

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Discussion.

Mr. Allen. Mr. W. H. ALLEN said that the Paper was entirely of a practical nature. He regretted that he had not been able to add the result of experiments; but those who knew the marine world would know the difficulty of getting ships for the purpose. He had supplied many such engines, but had never been able to get an opportunity of testing them. The committee of a kindred Institution were now engaged on this subject, and he hoped they would be successful in getting boats for the purpose of carrying out their investigations. He hoped that the Paper would afford scope for good discussion.

Mr. Willans. Mr. P. W. WILLANS said he had not had much to do with auxiliary engines for marine work, except those connected with dynamo driving; but as the Author had devoted a good deal of the Paper to that branch of the subject, there were a few points to which he should like to call attention, especially as the somewhat important question had been raised with regard to the relative advantage of single- and double-acting engines, with the design and manufacture of the former of which he had been connected for some time. Marine work was of a very peculiar nature, and manufacturers had usually no opportunity of learning anything as to the efficiency of their engines after they had once been fixed on board ship. They knew very little more about them in five years' time than they did at the outset; so that whatever tests they wished to apply must be made before the engines went on board. In addition they had to do with a curious class of men in those who drove the auxiliary engines. It was not as though the chief engineer had to deal with them—they were often in the hands of inexperienced men. It did not matter much what class of men they were, whether skilled or not; in fact, his own experience had shown him that the best men to drive engines for electric lighting were gardeners. What was wanted was men who were capable of doing what they were told, and willing simply to carry out their instructions. Such difficulties as he had encountered in connection with closed engines on board ship he had very rarely met with on land. They had been almost entirely of two kinds. First, difficulties caused by the enormous quantity of water found in auxiliary steam-pipes on board ship; and secondly, difficulties due to the imperfect understanding of the use of

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the oil-chamber in which the cranks ran, and to carelessness in not seeing that the lubricating mixture was replenished and in proper order. The first of the two difficulties mentioned above, viz., water, had been met in his case by the use of steam separators and by a more efficient system of escape-valves, so that it was now found possible to discharge suddenly into the steam-pipe of an engine running at 400 revolutions per minute a cubic foot of water, without any bad result. The second, viz., the quality of the lubricating mixture in the crank chamber depended solely on those in charge of the engines. On land practically no difficulties of this kind were now experienced, and by degrees, as the advantages of this system of lubrication both in economy of oil and of attendance were realized, he had no doubt that it would be more generally adopted on board ship. He could think of no course more likely to lead to this result than the use of open double-acting engines for the hard and continuous work of electric lighting at speeds of 320 revolutions, such as Mr. Allen appeared to advocate. The Author had spoken of the "single-acting closed engine," as though the two things were inseparable; but in reality the one was a question of principle, and the other, of convenience. For continuous work beyond a certain speed, he did not think that any one would recommend a double-acting engine. He was not speaking of occasional work; but for steady work, such as electric-lighting installations on land, and also on board ship, there was a speed at which double-acting engines were not applicable. The only question was, what was that speed? Closing up an engine was another question altogether. There were a number of different points to be considered, and there were certain advantages in having it open, and certain others in having it closed. His own reason for usually closing his engines was that there was nothing to be done to them, no adjustment of the bearings being required. This being the case, it was better to run the machine in a bath of oil rather than let it splash the oil in all directions. On the other hand there was a possibility of neglect. If the lubricant was run out of the chamber containing the cranks, &c., they were in a worse position with a closed than with an open engine. He had learnt by experience that it was very dangerous on board ship to put a cock anywhere if he did not desire it opened at intervals. If a stoker saw one, for instance, on the crank-chamber of a closed engine, he said to himself, "This cock would not be here unless it was wanted." The result was that sooner or later he opened it when the engine was running and let the oil out; and the consequences were not pleasant.

Mr. Willans.

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Mr. Willans. Sometimes even worse things than that were done. He had known, for instance, a case where an engine used for driving a capstan in a North Sea trawler had been opened up, and in which the only sign of lubrication in the crank-chamber was herring-bones, and scales, and salt water; and, although that might be taken as an extreme case, he had known others in which (in what ought to have been efficient hands) the lubricating mixture used had been hardly more effective, although perhaps less original in its nature. Those who were familiar with his engines would remember that there was an air-cushion to keep the pressure in one direction on the crank-pin. On one ship—and that not a North Sea trawler, but one of the largest ships in the Navy—the cock on the air-cushion cylinder was connected by a pipe to the bilge and kept open for hours together, under the impression that it was a drain-cock. This was the class of difficulty with which he had had to contend on board ship. He was at the present time constructing a number of single-acting open engines for use in the English Navy under Admiralty conditions, so that the matter could hardly be considered to be definitely settled in favour of double-acting engines for the Navy. The Author had not, however, contented himself with the statement that there were things to be said on both sides, but had said (referring to double-acting open engines), "It will also be seen that these engines have in themselves certain qualifications which give them an advantage over closed engines, namely, accessibility, simplicity, and economy, combined with the all-important point of durability." He then pointed out that the twin engine with cranks at opposite angles had the advantage of working with considerably less vibration than the single-cylinder engine. But this, although apparently included among the advantages of open double-acting engines, was not an advantage over the single-acting closed engine, which was usually made in the same way. He would take the Author's first four points—durability, economy, simplicity, and accessibility. First, as to durability. The Author's figures showed what he had found the best speed at which to drive double-acting engines. Speaking of circulating-pumps, he gave an account of the gradual slowing-down of the engines driving them. Beginning at speeds which were "not justified by experience," they came down to 100 and 120 revolutions, and the Author himself put 150 to 180 as the speed at which it was "quite possible to make such engines work with certainty." It would be instructive to consider what, at that speed, these engines had to do. Taking the only case for which the Author gave

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Mr. Willans.

diagrams, namely, that of an engine capable of developing 90 indicated HP. when pumping out the bilge, but doing in ordinary every-day work about 13 HP. The low-pressure cylinder under these conditions worked at a mean pressure of little over 2 lbs., and the high-pressure cylinder being about one-fourth the area of the low-pressure, the power developed in it was equal to 7 lbs. or 8 lbs. on the low-pressure; that was to say, the whole work of the engine was equal to 10 lbs. per square inch on the low-pressure cylinder. Was this "hard and continuous work?" He was afraid that engineers could not be content with that amount of work from an engine. Again, the Author had referred to the engine of the "Devastation" as having run for a very long time, and done "hard and continuous work." He believed that during the whole of the run referred to, there was 15 lbs. pressure in the steam-pipe, the engine exhausting into the atmosphere. They were working at that as a maximum, but it was only such work as a double-acting engine ought to do easily for reasons well known to those who had studied the problems connected with the inertia of the reciprocating parts. In comparison with that case he would like to mention two or three instances of single-acting engines with which he had been connected. The first to which he would refer was a fan-engine which had been working at the Woodthorpe colliery, near Sheffield, for some five years. It had run as much as nine months without being stopped, and it was locked up by itself at night. His partner, being down there on one occasion, asked to be allowed to see the engine. He was told that the man had gone home and had taken away the key. That was an engine indicating 100 HP. and running at 300 revolutions, the mean pressure on the pistons being 30 lbs., as compared with the Author's 10 lbs. It was regularly left running by itself in that way, and the bearings were oiled twice a week. The next case was that of a compound 80 HP. engine working with 40 lbs. mean pressure (referring all to the low-pressure cylinder), driving a dynamo for the electrical deposition of copper. Being a single-acting engine the bearings were as usual fitted up slack, and at starting and stopping when the engine was running slowly the slack of the bearings could be heard. After it had been away five or six months, the people wrote in alarm to say that at stopping there was a noise which they could not account for. He sent a man to see what was the matter, and it was found that there was, as they said, a thump on the bearings when they stopped; but the point was that it was five months after the engines had been started, and it was the first time they had been

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Mr. Willans. alarmed, for it was the first time they had stopped. He assured the owners that it would not happen until they stopped again; and, for anything he knew, the engine had been going ever since. Many electric-lighting stations had been started of late with insufficient plant, the demand for light coming on very quickly. The result was that at some of them the engines had been run far beyond their intended power. At the Kensington Court station, for instance, two 80 HP. engines had been running for more than two years without any examination or overhaul of the bearings. At the end of that two years, after working generally at full power, and during the times of greatest demand up to 100 HP., which required 50 lbs. mean pressure, referring all as before to the low-pressure cylinder—four or five times as much as that the Author had spoken of—they were still going on without any repairs to their bearings, just the same as at first. He wished in this discussion to be sure that they were considering engines doing the same kind of work, especially in comparing notes as to durability. Next, as to economy, the Author gave figures for water-consumption in the case of some of his engines for the Navy. They were employed to drive dynamos having an output of 400 amperes at 80 volts, and he gave the consumption of steam as 33·7 lbs. per electrical HP. per hour; but he did not say whether this result was obtained at his own works or at Portsmouth. Mr. Willans would compare with this the figures obtained in the case of the last six central-valve engines of the same power supplied to the Navy about six months ago. Three of these were running at about 390 revolutions and they gave a mean of 29·2 lbs. per electrical HP. per hour, the pressure of steam being 100 lbs. The other three were working (owing to the dynamos) at speeds of about 440 revolutions, and were consequently less fully loaded; the consumption in these was on the average 30·4 lbs. These figures were obtained during the tests at his own works. The average consumption of these six engines at Portsmouth came out $\frac{4}{10}$ lb. more than in his trials at Thames Ditton. The steam at Portsmouth contained when it reached the engines much more moisture than he had noticed elsewhere, and in two of the trials there were leaks in the pipes, &c., which brought up the average, so that the slight difference was easily accounted for; but he would take 29·5 lbs. as a figure which was constantly reached by his engines with fairly dry steam at 100 lbs. pressure non-condensing. Comparing this with the results obtained by the Author, 33·7 lbs., he found that for such work as incandescent lighting in the Navy, a saving of about 90 tons of coal a year

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would be effected in the case of his single-acting closed engine running continuously, as against the Author's double-acting open engine under the same conditions. Comparing it with the good substantial commercial engine with a single-cylinder, in the case of which 42 lbs. per electrical horse-power would probably be a fairly low estimate, the saving in running continuously would be something like 270 tons per annum. He asked, therefore, what became of the claim of superior economy? Mr. Allen might say that a part of this economy was due to the higher speed, to which he would reply that 400 revolutions was too much for a double-acting engine of this size for electric lighting, and that therefore the comparison was a perfectly fair one. With 130 to 140 lbs. pressure the consumption of steam per electrical HP. per hour was usually about 24 lbs.; and with condensing engines using high pressure it could be reduced to 18 lbs. per hour. The question of economy of coal was frequently overlooked on board ship in the case of the auxiliary engines. It was too often regarded as a small percentage of the total and therefore unimportant, but if any one were to say that because the coal used in London was a large quantity as compared with that used in an electric-light station, economy in electric-light stations was of no importance, he would not be listened to for a moment. The economy of fuel, although not the only thing to be considered, was of great importance on board ship as well as on land. The cost of coal was not, however, the only expense in running an engine—oil was used as well. The Author was silent on this point, but open engines, running at 320 revolutions, required a good deal of it. In the case of some of his 200 HP. engines running at Kensington Court and driving dynamos direct at 350 revolutions, the engineer, Mr. Miller, informed him that the daily consumption of oil for the bearings was half-a-pint for a run of from twelve to sixteen hours. It was very desirable that the Author should give particulars of the oil used in his 50 HP. engines at 320 revolutions. With regard to attendance, Mr. Willans thought it was hardly necessary to argue the point, as it was now generally admitted that with the single-acting engine, not requiring its bearings adjusted, much less attendance was necessary. As to the mechanical efficiency, he had put in a Table a few figures relating to engines driving dynamos by most of the best known makers, whose machines had been tried at his works. The first was one of the Navy engines running at 32·8 electrical HP., which gave 82·6 efficiency, or $\frac{\text{Electrical HP.}}{\text{Indicated HP.}}$ at a full load. That was a machine consider-

Mr. Willans.

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EFFICIENCIES AT VARIOUS LOADS OF WILLANS AND ROBINSON'S ENGINES COMBINED WITH VARIOUS MAKERS' DYNAMOS.

Engine No. . .		1,105	998	986	966	1,001 1,002 982	950	999	951	993	968	677
Dynamo maker .		Latimer Clark	Siemens	Goolden	Crompton	Johnson and Phillips	Chamberlain and Hookham	Elwell Parker	Crompton	Mather and Platt	Siemens	Siemens
Full load in Electrical HP. . .		32·5	60·8	62·0	67·0	68·0	68·8	81·0	148·3	149·0	242·0	44·25
Percentage Efficiency.	100 per cent. load . .	82·6	84·0	85·1	84·5	83·1	83·3	83·1	85·8	84·0	85·9	82·3
	72 per cent. load . .	80·2	78·5	80·0	80·3	..	..	78·5	81·0	77·0	81·0	79·8
	45·5 per cent. load . .	71·0	71·0	71·9	72·2	..	..	67·5	73·1	69·5	72·8	75·3
	24·5 per cent. load . .	59·9	59·9	58·1	56·9	..	..	54·8	58·9	54·9		
	12·8 per cent. load . .	44·8	42·0	40·5	40·4	..	..	40·4	42·2	40·0		

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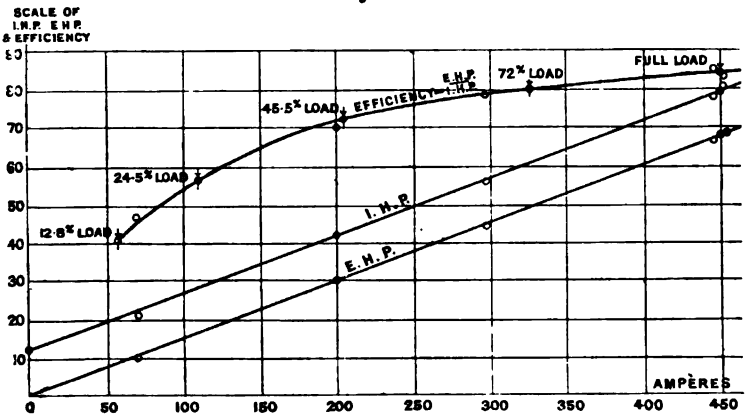
ably smaller than that spoken of by the Author. The figures given were not chance cases, but were representative ones, the full power varying from 32 to 160 electrical HP., and the efficiency rising in some cases to 86 per cent. It might be interesting to point out that if an engine was very fully loaded, a higher efficiency was necessarily obtained at the lighter loads; for they worked in the better part of the curve, so that it was important to know in comparing light-load efficiencies how heavily an engine was loaded. *Fig. 3* showed the way in which he usually set out the results. The electrical HP. was represented by the lower diagonal line, and the indicated HP. by the upper one; the efficiency curve showed the electrical HP. divided by the indicated HP. If the

Mr. Willans.

Fig. 3.



CURVES OF EFFICIENCY—I.HP. AND E.HP.

Engine, No. 966; Crompton Dynamo, No. 2,035; constant volts, constant speed, observed points=0.

curve was carried out by increasing the power the efficiency would be slightly increased, and bring the quarter load further to the right, and so into the better part of it. That partly accounted for the differences in efficiency at the light loads shown by the Table in some cases, the more heavily loaded engine, other things being equal, coming out better at light loads. He had observed that the Author gave his figures for efficiency for ordinary commercial engines. In comparing them with those given in Mr. Willans' Table, which were all for compound engines, it must not be forgotten that although the dynamo might in such cases be slightly inferior to those constructed to pass Admiralty tests, yet this would be at least compensated by the reduced friction of

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Mr. Willans. the single-cylinder engine employed. He always found that his simple engine gave a rather higher mechanical efficiency than his compound engine when used for equal loads, the increased economy in steam per electrical HP. in the latter being realized in spite of this mechanical disadvantage. With respect to the two other claims made by the Author for his engines—accessibility and simplicity—it was impossible to judge of the simplicity, as the details given were so meagre that no opinion could be formed one way or the other; he could not for a moment agree, however, that they were necessarily more simple in construction than closed single-acting engines, and they certainly were not so easy to drive and to adjust. He did not see how such engines could be simpler to work than those in which the cranks, connecting-rods, and valve-gear, could be all lubricated once a day through one oil-hole, and in which the bearings never needed small adjustments. As to the general question of speeds, he ventured to say that if double-acting open engines of 50 or 60 HP. were used in the future, in the merchant service or the Navy, they would be run at much lower speeds than 320 revolutions per minute, and that even then their use would entail greater bulk and weight (especially for the dynamo), and increased first cost, together with reduced economy in every respect as compared with well-designed single-acting engines, the working parts of which could be run at a comparatively high speed in a bath of oil. There was one other point; the Author, in referring to the question of governing, mentioned that one of the greatest improvements on board ship was that of fly-wheel governors. With that Mr. Willans quite agreed. In marine engineering, where they ought not to want any adjustment in speed, it was impossible to have too powerful a governor; but on land, where very often everything turned on being able readily to vary the rate at which the engine was running, it was doubtful what would be the best thing to do. He found that electricians wanted more and more a variable speed for electric-lighting engines, and in fewer instances an absolutely constant speed, unless it was in stations where the alternating current was used. On board ship, where dynamos could be compounded, they ought to have the speed constant, and the more powerful they could make the governor, and the less accessible while running, the better it would be. He found no difficulty in regulating the speed within 2 per cent. and 3 per cent. by means of a governor on the crank-shaft (not a fly-wheel governor) in cases where the weight of the fly-wheel was not limited by other considerations.

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Mr. F. E. DUCKHAM said the Author had dealt very fully with the question of machinery for applying forced draught to steamships. The great point to be considered with respect to such inventions was whether they were commercially successful. During last session Mr. White, the Chief Constructor of the Navy, in a Paper read before the Institution of Naval Architects,[1] gave some particulars with reference to the use of forced draught on board Her Majesty's ships. He there stated that on the "Howe," whereas by natural draught they attained 8,200 indicated HP. and 15·9 knots speed, when using forced draught they obtained 11,600 indicated HP. and 16·9 knots speed, an increase of 40 per cent. in the HP. and of 6 per cent. in the speed. Then with reference to the "Medusa," natural draught gave an indicated HP. of 6,300 and 18 knots speed; which under forced draught was brought up to 10,000 indicated HP. and a speed of 19·9 knots. These results were obtained on trial trips, but it was of the utmost importance to the commercial world to know, not what took place on a trial trip, when everything was worked up to the highest point of efficiency for the time being, but what had been the result of voyages of ordinary steamships, out and home, with and without forced draught; so that they might get some accurate means of comparing the effect of the two systems on steamers of the ordinary type. It had, moreover, been found that great damage had been done to the boilers by forced draught, and orders had been issued in some quarters that it was only to be used in cases of emergency and for short periods. This circumstance made it more necessary to consider how far it was applicable for commercial purposes. It had been said that marine boilers gave way probably because of the intense heat in their furnaces; but it must not be forgotten that there was intense heat also in the fire-box of locomotives, where however the draught instead of being forced was induced by the exhaust of steam into the funnel. That led to the question whether the present type of marine boiler was the correct one, and whether to use forced draught with these boilers was not like trying to make an old-fashioned tool do for present-day purposes. He remembered Mr. Yarrow referring in that Institution to the water-tube boiler introduced by him. He had since seen it at work, and was considerably impressed with its efficiency and simplicity. It was a first-rate thing for torpedo-boats. Mr. Yarrow had not designed it for large sea-going vessels, but he believed it was a departure from the present style of marine boilers that might lead eventually

Mr. Duckham.

[1] Transactions of the Institution of Naval Architects, vol. xxxi. p. 12.

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Mr. Duckham to the satisfactory application of forced draught. Mr. Duckham had lately been engaged in various experiments as to the transmission of grain by the medium of air, and found that induced draught or suction utilized the power employed far more efficiently than air under pressure. Some years ago, when the telegraphs were taken over by the Government, a series of experiments were made as to the relative efficiency of compressed-air and of a vacuum for the transmission of messages, and a Paper by Mr. Preece was read before the Institution,[1] showing that there was a great advantage to be obtained by working the tubes under suction instead of pressure for the purpose in question. The advantage was not constant in amount, but was greatest between the higher pressures and greater vacuums, and diminished as atmospheric conditions were approached. He was not prepared to say if that reasoning was directly applicable to the question of the small pressure of draught which would be used for the furnaces of marine boilers. There was one other point in relation to the auxiliary engines of steam-ships. He might be thought foolish for saying that the greater number of vessels which were lost at sea were lost because they were not enabled to keep themselves afloat, nevertheless it was a melancholy fact. It might be taken in round numbers that the effective HP. of the boiler, if suitably employed, would enable a vessel to throw out something like half a ton of water a minute for each HP. Taking the vessel referred to by the Author, with 13,000 HP., it should, under such circumstances, be able to pump 6,500 tons a minute. The ship would need to be cut in two to admit the quantity of water which such power could discharge, but if they took one vessel with another, it would be an exception to find that they had sufficient pumping appliances to throw 20 or 30 tons of water a minute. This left a large margin of power unapplied. It was important that artificial draught and marine boilers should be improved upon, and whatever could be done in the direction of economizing coal, and reducing the weight of the boiler, so that the vessel should be able to carry a larger quantity of freight, would be a great commercial advantage, although the question of the ship's pumps was more important in relation to the loss of property and life at sea.

Mr. Terry. Mr. S. H. TERRY said the Author, in speaking of forced draught on the "Majestic" and "Teutonic," seemed to imply that the air by which the furnaces were kept going was supplied

[1] Minutes of Proceedings Inst. C.E. vol. xxxiii. p. 34, and vol. xliii. p. 87.

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entirely by the four fans which he had built for those ships. He would like to ask more precisely what work the Author's fans were doing in connection with the forced draught of the ship, because he was under the impression that there were fourteen fans and engines supplied by the firm with which he was connected, Messrs. Bumsted and Chandler, which were used for that purpose. He would like to know whether those fans had been taken out, or whether the Author's fans were not really doing quite another work, namely, ventilating the stokeholds. From the Paper it might be implied that these fourteen fans were not in existence. He had been informed by the engineer of one of those ships that only a Chandler engine or fan could endure the temperature in which those fans were working, for they were down in the casing immediately round the boilers. They did not get much of the credit for the work, because they were not seen by the passengers at all. He would also like to know whether about the time that the increase of speed took place, when the Author's fans were put in, it was a fact that the screws of the "Teutonic" were altered, and whether their being put to a rather different pitch might not have something to do with altering the speed of the ship. He might mention that the Chandler fan and engines had been running on these ships at a speed of 350 revolutions per minute, each being capable of supplying some 16,000 cubic feet of air, or in all 224,000 cubic feet of air per minute in each ship. There were 3 inches of water-pressure in the fan-casing; but that was very much reduced by the time it reached the closed ash-pits, in consequence of the friction in the air-trunks. In addition to the forced draught, three other Chandler engines were employed in each ship in ventilating the refrigerating chambers, and the screw tunnels. He was entirely in accord with Mr. Duckham as to improving the pumping-arrangements on board ship. It was a matter in which he had taken interest for some years. As long ago as 1880, on the occasion of the loss of the "American" off Cape Palmas on the African coast, he began a correspondence, which was followed up by others, in 'The Engineer' and 'Engineering' on the subject of fitting ships with more powerful pumping machinery. It seemed an anomaly that a large vessel should be dependent upon her crew, and in some well-known cases of shipwreck on her passengers, to assist in working the pumps. Of course the whole power thus available was nothing in comparison with what could be applied if the steam in the boilers could be brought to bear on proper pumps. It was evident that

Mr. Terry.

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Mr. Terry since the date he alluded to, progress had been made in that direction, and the pumping engines were now nearly always connected with the bilge. He did not claim to have originated the idea of doing so, but merely stated that he was one of those who brought prominently forward the necessity of increasing the pumping power on board ship. It was not, however, of much use fitting powerful pumping machinery unless the pipes and valves were large enough to pass the water that a centrifugal pump would draw, and he had known cases in which pumps and engines and steam-pressure had been good, but the pipes had been so restricted in area that they were unable to carry the water, and there was no chance of working at full power. With regard to the use of auxiliary engines on board ship, he felt convinced that the engine of the future, for fan-driving, and for dynamos and centrifugal pumps, would be single-acting, either compound or triple-expansion, for this type had been proved to be the only one which could run continuously at anything like the speed requisite for direct-driving without knocking, or undue wear and tear. On this head he might state that his firm had received most satisfactory accounts from the superintending engineers of the fleets of the following steamship companies, in which their engines and fans and engines and dynamos had been almost continuously used: namely, the British India Company, dynamo-driving; Messrs. Herskind and Wood, under Mr. Fothergill's system for fan-driving for forced draught; the White Star Company; the Peninsular and Oriental Company; on the Carron Company's fleet, for electric lighting; and numerous other companies which he need not mention. In some cases the engines had been running for six years, and were as good as when put in, although making 400 and 500 revolutions per minute for several weeks at a time, and taking steam at pressures up to 180 lbs. to the inch. In numbers of steamships he could name, the electric-light engines and centrifugal-pump engines of the double-acting open (direct-driving) type made nearly as much noise as the main engines of the ship, which were exerting a hundred times more power, and it was unsatisfactory alike to the engineer, the passengers, and the crew, to have the efforts made to produce a quiet engine-room frustrated by the knocking of auxiliary engines, which in cases he had come across, were audible all over the ship. As regards steam yachts the silence of the electric-light engines was of great importance. Yachts were now largely used by professional and business men to recruit their energies. Every steam-yacht owner wanted the electric light, but unless single-acting engines

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were used it could only be obtained (in harbour when the main engines were standing) at the sacrifice of quietude. Railway companies were frequently and properly accused of conducting their traffic with a needless amount of noise, produced by whistles, escaping steam, vacuum-brake ejectors, careless shunting, &c., and he expected that at no distant date we should become too highly civilized to tolerate barbarous and unnecessary sounds. Most people were accustomed to think of a ship, except during bad weather, as the abode of peace and quietude, but this would be a thing of the past if engines making a knocking and hammering were used, and on this account therefore he felt convinced that the single-acting high-speed engine was the standard type of the future for auxiliary purposes. Mr. Terry

Mr. Reginald Bolton said the Author had shown illustrations of a number of applications of small engines to various purposes on board steam vessels. These engines were distributed about the ship at different distances from the source of power—namely, the boiler. There were others which were not described, such as the steam-winches, capstans, windlasses, and so on, amounting in some of the larger vessels to a considerable number. The engineer of the "Arizona" told him that he had under his charge in that vessel as many as seventy steam-cylinders—quite a conglomeration of material for losing power, if he might put it in that way, as well as for doing necessary duties. He was convinced that in a vessel of that kind the power should be distributed in the most economical way possible, and if details of the working of those small engines in the various parts of the ship could be obtained some means of improvement might be found. In addition to losses in the engines there were losses in the pipes, which must be considerable in large vessels. The only criterion they had of the amount of steam used by these small engines was that the donkey-boilers of cargo-steamers were being made larger and larger. A case recently came before his notice where a cargo-boat of moderate dimensions had to have a donkey-boiler put in equal in size to one of the main boilers. That evidently indicated considerable losses in the small engines. Amongst those which had been described by the Author there was one which seemed to show an efficiency superior to that of the others. It had been stated that the efficiencies of the fan-engines were very low, and the Author did not bring forward figures as to the pumping-engines, but he did so with reference to electrical-driving engines, and both he and Mr. Willans agreed that as much as 80 to 82 per cent., and as Mr. Bolton was informed, even up to Mr. Bolton.

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Mr. Bolton. 84 and 85 per cent. had been reached by engine and dynamo combined. It appeared, therefore, that if electrical driving was ever to come into use anywhere, it would be suitable on board ship, where a distribution of power was required, and where under present conditions, an immense amount was wasted. If the dynamo and engines were of such a size as to be able to supply a number of these smaller machines with the power which was required, the losses should not be greater than they were at the present moment. The efficiency of the motor already stood as high as 80 per cent., and would probably be made even greater. They had therefore to deal with an efficiency in the electrical producing plant of 80 to 82 per cent. together with a loss in transmission which might be said to be 1 to 2 per cent. of that amount, and an efficiency of the motor of 80 per cent. He could only say that this was superior in its results to the present state of things. Taking as an example the steam-winch, which was some hundreds of feet from the boilers in most vessels:—Before it could be started, the whole of the pipe had to be heated, which involved an amount of loss which must be serious. When it did start, they had two small cylinders, 7 inches by 10 inches or 8 inches by 12 inches, working with a cut-off in some cases three-fourths and in some seven-eighths of the stroke, throwing the steam out of the ship's side in a manner familiar to any one who visited the docks. It would be an improvement if these small engines scattered about the ship and connected by long lines of steam-pipes could be done away with, and electrical motors used in their place. He put forward this suggestion with diffidence, but it appeared to find some confirmation from the figures which the Author and Mr. Willans had laid before them as to dynamo-driving.

Mr. Siemens. Mr. A. SIEMENS wished to say a few words in the same sense as the last speaker as to the disadvantages of the present auxiliary engines, many of which were arranged so as to take their steam-supply from the main boiler, as well as from the donkey-boiler, and had their exhaust connected with the main condenser, and as an alternative, with the open air. This arrangement naturally led to most of the auxiliary engines being much too large for their work, and to their being fitted with a multitude of pipes in which the working of the ship caused constant leaks, giving frequent employment to the fitters on board. The same remarks applied to hydraulic pipes. He hoped to exhibit a complete set of auxiliary engines driven by electric-motors for ships' use at the coming Naval Exhibition, when he

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should be in a position to speak more fully. The principal difficulty connected with employing the electric motor, as, for instance, in the case of a winch, was that the winch had to exert the pull on the rope without actually moving. The consequence was that an excessive current would pass through the armature of an ordinary motor, and it would probably be damaged. That was the chief reason why electric motors had not sooner been employed in such auxiliary engines, because the danger of damaging the armature through a sudden stoppage could not be avoided. He thought they had overcome that difficulty, and they intended to exhibit a fan, a winch, a capstan, and a machine for closing watertight doors of an ironclad. The way in which these auxiliary engines would be worked was that there would be one main auxiliary engine, so to speak, which would drive the dynamo machine with the best efficiency, and under the immediate eye of the engineer. All the other motors could be practically left to themselves, proper precautions being taken, so that no excessive current could reach the armature. With regard to the lasting qualities of the motor, he thought he could cap Mr. Willans' remarks about the gardener, by saying that at Sir William Siemens' place at Tunbridge Wells there was an electric-motor for pumping water into the house, which was worked for six hours on three days of the week; it had been used ever since 1878 or 1879; it had only been looked after by a gardener, and it never gave any trouble. There was no reason whatever why all electric-motors should not be equally manageable, if only proper care was taken to make them large enough, and to prevent an excessive current reaching the armature. Mr. Siemens.

Mr. PREECE said Mr. Siemens had omitted to mention perhaps the most important point in favour of the introduction of electric-motors on board ship in preference to small steam-engines. Speaking particularly of one large man-of-war, which he saw a short time ago at Malta, he found that there were no less than eighty-six engines on board, and the ship was permeated all over with steam-pipes. He was told that in hot countries those pipes added some 10° or 15° to the already unbearable temperature of the country, and as the commander of the ship stated, electricians could not confer a greater boon on the navy than by the introduction of electric-motors which would enable them to remove the steam-pipes, and thus lower the temperature of the ships, which were in some cases absolutely ovens. Mr. Preece.

Professor GEORGE FORBES had noticed a slight misinterpretation of the results given by the Author and Mr. Willans, which Professor Forbes.

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Professor Forbes. Mr. Bolton introduced, and which might lead to a misunderstanding. Mr. Bolton mentioned the 80 per cent. efficiency, or greater, which had been referred to as the efficiency of the engine and dynamo combined, and proceeded to say there was 1 or 2 per cent. loss in the mains, and there would be then an 80 per cent. efficiency in the motor. It was over-looked that the 80 per cent. efficiency of the steam-engine and dynamo combined was to be taken as the ratio of the HP. developed electrically by the dynamo machine to the indicated HP. Therefore, when they were dealing with a motor the efficiency was not 80 per cent., because the steam-engine had nothing to do with it. It was probably more like 92 or 93 per cent. That was a point that added very considerably to the total efficiency of the system, beyond what Mr. Bolton had spoken of. He agreed with what had been said by Mr. Preece as to the enormous value of electrical transmission on board ship by means of wires instead of steam-pipes. At the same time, since the engines that had been spoken of chiefly as being benefited by the use of electricity happened to be the steam-winch and the capstan, he might point out that there was a rather serious trouble, in some services, connected with the employment of electricity for those two purposes, though not for the machinery in the body of the ship. Any one who had, like himself, crossed the Atlantic at that period of the year, with a strong north-westerly wind, and the temperature below zero, would remember how, for several days before reaching port, it was necessary to keep the steam on the engines of the winches and capstan, in order to prevent the accumulation of ice, which might interfere with the working of them when they arrived in port. That was the difficulty that must occur, and which he felt to be almost insuperable when ships were trading in temperatures where there was likely to be a large accumulation of ice over certain parts of the machinery.

Mr. Kapp. Mr. Gisbert Kapp said that several speakers appeared to think it was an easy thing to put an electric motor on board ship, and to use it for the purposes mentioned with the highest possible efficiency. It seemed, however, that one important effect was lost sight of: the high efficiency of 92 per cent. was quite attainable in 100 HP. machines when steadily running at the normal speed, but with a machine that was turned on and off they could not get anything like as much. The electric motor was very efficient if it had a full or half load, and could run at a full and constant speed. On board ship, however, what was wanted was to give a half turn of the winch and then stop; it was nothing but stopping and starting,

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and under such conditions an electric motor was just as bad as a slipping belt; the current went through, but produced little motion. He was afraid that for intermittent work of that kind they could hardly introduce electricity at present; they must first of all find a way of gearing motors running at a constant rate, by apparatus permitting a variable speed to be communicated to the capstan or winch, or whatever was being driven. There were other purposes on board ship for which motors might be used with great advantage; they could drive pumps, ventilators and various other machines. He did not wish to throw cold water upon a subject as to which he was himself an enthusiast, namely, the transmission of motive power by electricity; but on the other hand, he did not think it was right to let members run away with the idea that it could be done very easily. He wished to ask the Author about a passage in which he stated, speaking of the amount of cold water which must pass through the tubes of the condenser, that there was a particular quantity which was the best. He could understand one limit which the Author had given when he said, "Should the surface not be enough, or the condensing-water insufficient in quantity, then the vacuum obtained will be lower than that desired;" but the other he could not quite understand, namely, when he continued, "On the other hand, if the circulating-pumps deliver too much water, the condensed steam is reduced to a temperature below that at which it is economical to return it to the boiler." That was in a manner opposed to the well-known thermo-dynamic law, which stated that the greater the difference of temperature at which they worked, the more economical was the process; whereas they were now told they must not have too good a vacuum. He would ask the Author whether there was really such a point below which they must not go. With regard to the governor, he quite agreed with what Mr. Willans had said, as to its being adjustable for land engines. They were generally compelled, or they found it at any rate exceedingly convenient, to use at central stations shunt-wound dynamos which gave rather a higher pressure when lightly loaded and a lower pressure when fully loaded, even when the speed remained constant. The speed, however, would slightly vary, and he did not know of any governor which would keep an engine absolutely constant under great variations of load, so that the imperfection of the governor increased this variation of electric pressure. The engine ran a little faster with a light load, and the dynamo itself gave more pressure with a light load. The Author's firm had been perfectly successful in providing a governor adjust-

Mr. Kapp.

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Mr. Kapp. able while running, in two steam-dynamos made to his specification, and in which it was one of the conditions that the governors should not allow the engines to hunt. He was pleased to say that the engine had fulfilled both conditions in a very satisfactory manner.

Sir Frederick Bramwell. Sir FREDERICK BRAMWELL said with regard to an ordinary winch for the purpose of unloading a cargo, Mr. Kapp need not be alarmed as to the necessity of stopping and starting. The common practice was to keep the winch running constantly, and simply by holding on the fall or slacking out the fall, to make the winch raise or even lower, and to regulate the pace of lowering, although it was always running in the lifting direction.

Mr. Cowper. Mr. CHARLES E. COWPER said that the system of forced draught was a matter of great interest, since theoretical considerations tended to point to it as a possible direction in which to obtain more economy in the use of steam, as well as a greater production from a given plant. The manner in which the Author had stated the advantages obtained by the use of forced draught might be satisfactory, from a commercial point of view, but it appeared to an engineer very crude and unsatisfactory. He told them that in the case of the "Majestic" and also in that of the "Teutonic" forced draught had been the means of considerably "increasing the speed of the vessel." Now it was obvious that the speed of a vessel depended upon the speed at which the screw was driven by the engines, and that again depended on the supply of steam by the boilers. It was the work of the boilers that was actually affected by the forced draught. It would be of interest if the Author could give them some figures with regard to the increased evaporation, showing how it affected the economy; and, further, as to the condition of the boilers, and whether they were at all injured by the heavier firing.

Mr. Beaumont. Mr. W. W. BEAUMONT thought Professor Forbes intended to warn engineers generally that they might be misled with regard to some remarks which had fallen from Mr. Bolton as to the efficiency of electric motors. But he told them that the efficiency might be 90 per cent. instead of the 82 per cent. as on Mr. Willans' diagrams. So far as a motor was concerned, that of course was quite correct; that was to say, a motor might give as mechanical HP. 90 per cent. of the power electrically represented by the current supplied to it; but the generator and engine, not having an efficiency at the very outside of more than 86 per cent., the 90 per cent. efficiency for the motor would be reduced to $0{\cdot}86 \times 0{\cdot}9 = 77{\cdot}4$ per cent. at the best, and in many cases it would

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only be about 70 per cent. which could be calculated upon or obtained in motors even of considerable size. He thought Professor Forbes had intended to complete his explanation in this way. Mr Beaumont.

Mr. H. W. RAVENSHAW said that, with steam donkey-engines, there was a great loss from the condensation of steam in the pipes, which would be almost entirely obviated by the use of electro-motors. He had employed a high-speed double-acting open engine for electrical testing, and on measuring the consumption of coal and oil, found that, when giving about 20 brake HP. for ten hours, it used 10 cwt. of coal, costing 4*s.* 6*d.*, and 1½ gallon of oil, costing 5*s.* 3*d.* The cost of oil with improved lubricating arrangements had been since reduced to about 3*s.* 6*d.* These figures showed the necessity of providing efficient means of lubrication for this class of engine. Mr. Ravenshaw.

Mr. G. B. OUGHTERSON, while regretting that Mr. Brotherhood was not present to take part in the discussion of this question, desired to say a few words on the subject of forced draught. Mr. Brotherhood had had considerable experience in this matter, having supplied upwards of eight hundred fan-engines for that particular purpose. The Author had said "at present there is no general consensus of opinion on the subject of forced draught, . . . but as regards quantity, it is safe to take as a liberal allowance 260 cubic feet of air per pound of coal." Now 260 cubic feet of air would weigh about 21 lbs., and inasmuch as competent authorities gave 18 lbs. as the quantity actually necessary for the proper combustion of 1 lb. of coal under forced draught, he considered 260 cubic feet to be far from a liberal allowance. The Author somewhat qualified his statement by adding, that considering the waste through leakage, &c., it might be prudent, under some circumstances, to add considerably even to the liberal allowance he mentioned; but Mr. Oughterson's experience was, that with forced draught in closed stokeholds, they would have to add considerably to, in fact, would have to go to nearly double the quantity that the Author had stated. It might be that the Author had calculated the quantity of air necessary for forced draught on the same basis as that on which he had estimated the yield of fans which were mentioned in the Paper as having been fitted on the "Majestic" and "Teutonic." These fans, 7 feet 6 inches diameter, running at 250 revolutions per minute, were said to be capable of giving out 50,000 cubic feet of air per minute; but taking a moderate percentage of the fan-tip velocity as that of the air through the inlets, and given a perfectly free delivery, he thought it would be found that the quantity Mr. Oughterson.

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Mr. Oughterson.

of air delivered ought to be very much in excess of that stated in the Paper. The Paper went on to state that "it having been suggested by leading authorities that a central diaphragm would add considerably to the efficiency of the fan, the Author had carried out a series of experiments on the subject, and had satisfied himself that no benefit whatever accrued from its introduction . . . but the trials proved that the bosses having curved entrances to about the diameter of the inlets were in every way as efficient as if the diaphragm had been carried right through." He fancied the "leading authorities" to whom the Author referred were the same as those who had suggested the diaphragm to Mr. Brotherhood; and so far as his memory served him, it was never a question of carrying the diaphragm "right through," but of carrying it far enough to cause the two opposing currents to diverge; and it appeared to him, that having extended the bosses to about the diameter of the inlets, the Author had done all that was intended. With regard to electric-light engines, he might speak with some little authority, seeing that about eleven hundred of Mr. Brotherhood's engines had been supplied for the purpose of driving dynamos. Some of these had been at work for periods far longer than that mentioned in the Paper, during which the Author's double-acting engine was fitted on H.M.S. "Devastation," and were working, he had every reason to believe, most satisfactorily. He agreed with Mr. Willans, that the closed single-acting engine had scarcely had fair play. Double-acting open engines appeared to be, for the moment, in greater request, and manufacturers were therefore more or less forced to meet this demand, but the single-acting closed engine was susceptible of numerous applications, and in many cases found its place where it would be impossible to apply a double-acting engine, and it could be worked with marked economy as regards fuel and oil. Mr. Brotherhood had at his works two of his 3-cylinder single-acting compound engines, which had been running since 1884, each giving out about 22 HP. with 100 lbs. initial steam-pressure, one making 750 revolutions, and the other 650 revolutions per minute: these engines had cost very little for repairs, and were practically in as good order as when they were started. Another of a similar class had been at work since 1885, running at 600 revolutions, and with the exception of new piston-rings, had never had any repairs done to it. Altogether, he thought that the single-acting closed engine, whether of the Brotherhood type, or of the Willans type, had in many instances great advantages. He had thought it well to call attention to what, rightly or wrongly,

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appeared to him to be a misconception with regard to the quantity of air required for forced draught, but his observations must be taken as referring exclusively to the closed-stokehold system, and not to the closed-ashpit system, as of the latter he had no experience. Some reference had been made as to the failure of certain boilers under the action of forced draught. To his knowledge, the mail steamers on the Dover and Ostend route, built and engined by Messrs. Denny and Co., of Dumbarton, two and a half years ago, and working with forced draught on the closed-stokehold system, had been doing service constantly and well with a pressure of from 1½ inch to 2 inches of water in the stokeholds; each steamer was fitted with four Brotherhood engines and fans, the fans being 5 feet in diameter. Mr. Oughterson.

Mr. W. H. Allen, in reply, said it would be almost impossible to have a Paper read in that Institution upon high-speed engines, or the economy of water-consumption, or on any kindred subject, without Mr. Willans taking part in the discussion. They all knew what he had done, both in practice and in theory, and his writings should be studied by all young men. He was sorry to hear the apology that Mr. Willans had to make as to the men necessary for working the engine; doubtless it was owing to the fact that many mishaps had occurred, for although his engines were so well known and gave universal satisfaction on land, they did suffer from *mal de mer* as soon as they got to sea. Whatever might be the reason, he had come across a number of them which, from one cause or another, gave considerable trouble. He believed it was due principally to the abundance of water which was always to be found in steamships. Since Mr. Willans supplied his first engines to the Navy years ago, they had no doubt been very much perfected. In reference to the low speed of the circulating engines, to which he had called attention, namely, 150 revolutions a minute, it must be remembered that while dynamo-driving was one thing, circulation was quite another. The ship depended for its very existence on the main engines. It did not much signify if a light went out, but for the circulating engines to stop was a serious matter, and superintending engineers did not see their way to go beyond the present number of 130 to 140 revolutions. He had raised it to 150, and thought they could afford to work at that speed without any possibility of a breakdown. With regard to the long run of one of Mr. Willans' engines, it so happened that Mr. Allen had had an exactly similar experience. Some of his engines on the "Devastation" had been working for many weeks without change over. Mr. Willans asked Mr. Allen.

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Mr. Allen whether the experiments with regard to the water consumption were made at Portsmouth or in their own works. The figures he had given were obtained at Portsmouth. The rules there were extremely rigid and well understood, and it would have been foolish to make any experiments in their own works, and expect them to be improved at Portsmouth. Mr. Willans pointed out that his engines had proved more economical by 29·5 to 33·7. Every engine-maker must give way to Mr. Willans as having introduced the most economical design, but the economy depended upon the increased speed at which that particular form could be driven. Mr. Willans' engines gave a consumption of 29·5 lbs., with 440 revolutions, whereas his (Mr. Allen's) engines, with 33 lbs. only, travelled at 320 revolutions. That must be taken into consideration in comparing their respective values. He was very glad to see the Table that Mr. Willans had brought forward, because it was a proof that they were not so far behind with the double-acting engine. Mr. Willans had claimed an efficiency of 82·3, whereas Mr. Allen's firm had reached in their trial with ordinary mercantile engines 81·2, so that they were only 1 per cent. under Mr. Willans under the same circumstances; with a speed of 440 revolutions against their 320 with engines of 44 indicated HP.

Mr. Willans. Mr. WILLANS remarked that those figures were obtained three years ago; at present the efficiency was about 1 per cent. higher.

Mr. Allen. Mr. ALLEN said in that case they were 2 per cent. behind Mr. Willans. It should further be noted that the high efficiency of 85·9 per cent. on the Table was obtained with engines of much greater power, namely, 240 HP. With regard to the governor, he had only given one example, namely the fly-wheel and governor, which he had spoken of in the Paper as applicable to marine work, but they also had a variable governor, which would almost equal it in point of precision. There could be no doubt that, as Mr. Duckham had said, forced draught was a commercial success. In no case that he knew of had there been a failure. On the Inman Line the best paying steamer was the "Ohio," which was fitted with forced draught, and the "City of Paris" at the present moment was undergoing a change for the same system. He thought that the term forced draught was misapplied at the present moment, and that assisted draught was a better expression to use. In the paddle-steamer "Victoria," running between Dover and Calais, the speed of the boat with natural draught was 15 knots, and under forced draught 19 knots, with a pressure of

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about 2½ inches. At that speed the boilers began to give considerable trouble, and were voted by no means a success. But by reducing the speed of the fans one-half, getting a pressure of 1½ inch, they obtained 18 knots without any trouble whatever to the boilers or machinery; so that in that instance natural draught gave 15 knots, assisted draught 18 knots, and higher forced draught 19 knots, showing the advantage of assisted draught as against forced draught for commercial success. He was afraid that Mr. Terry had commenced with the wrong paragraph of the Paper, and had omitted to notice that in which he said with regard to the fans on the "Teutonic," "The application of fans, however, may have a two-fold purpose, namely, to enable more coal to be burnt in a given time, and also to reduce the temperature of the stokehold, which is always a most desirable object." The Paper went on to show that fans had been introduced into the "Majestic" and "Teutonic" under those circumstances. What were the circumstances? To burn more coals in a given time, and to reduce the stokehold temperature—not as forced draught. The orifice by which the air was taken to the stokehold was too small for ventilating purposes, and also for supplying forced draught; consequently they fitted large fans for the purpose of supplying the stokehold with air in order to feed the fans below. Sufficient coal could not be burnt before they were furnished with this assisted draught. Coming to the observations of Mr. Bolton and of Mr. Siemens on the same subject, he had not lost sight of the fact that electricity might form an important agent in the auxiliary machinery of ships in the future. With regard to Mr. Terry's statement that the single-acting high-speed engine would be the standard type of the future, the Author was of a different opinion. The same observations had been made regularly for the last ten years by advocates of this engine, but results went to show that the single-acting engine was as far off universal approval as ever. At the present moment it was not accepted by the Royal Navy in any form at all, after every consideration had been given it, and in the mercantile marine, from the Author's own knowledge, of a very extended character, he could safely say that fifty double-acting engines were in use to one of the other type, so that until the single-acting engines could be radically improved, and the difficulties which had hitherto accompanied the working of them had been overcome, the Author felt sure that the double-acting engine would still retain its position in the marine world. It was not to be supposed that it could not be made to run quietly, for when constructed of proper material, with ample bearing

Mr. Allen.

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Mr. Allen. surfaces, and accurate workmanship, coupled with a careful distribution of steam, this form could be relied upon for silent and constant working as well as any other. Mr. Preece mentioned that in one of the ships of the Royal Navy at Malta they had eighty-six engines on board. That would not bear comparison with the mail boats, as probably seventy of those were idle during ordinary times. On the "Normannia" there were thirty-six auxiliary cylinders which were necessarily always at work to assist the main engines. That gave rise to the question whether some other means could not be devised of concentrating these small engines under one head. Electricity was the only thing they could think of. At present they were endeavouring to see how far that would assist in driving the fans themselves. He did not know whether it would be applied to driving pumps, although that might be done later on. A serious obstacle prevented the introduction of electricity for that purpose at present: while it enabled them, by increasing the speed, to reduce the diameter of the fans considerably, and thus to make them occupy a smaller space in the ship, there was this one objection to it, viz., the extremely high prime cost. In the case of the "Normannia" they found that the increased cost of a set of motors and fans, together with generating plant, would be something like £3,000 over and above that of the present system. Every shipowner shook his head directly that was mentioned by way of experiment or otherwise. The poor duty obtained from the small fan-engines would be balanced to a great extent by the large generating plant being confined to one small central station, so that it was quite likely it would come into use when they had better motors to assist them. With regard to Mr. Kapp's remarks as to the reduction of temperature in the condenser, it was well known to all marine engineers that they would rather have a poor vacuum, so long as they could keep up the temperature of the feed-water. Mr. Ravenshaw's remarks with regard to the consumption of oil in double-acting engines were scarcely consistent with well-known experience. The Author found that an ordinary dynamo-engine, indicating 60 HP., would usually work for six hours, with a consumption of oil of nine pints. With reference to Mr. Oughterson's criticism, the quantity given of 260 cubic feet of air required per lb. of coal was one which he had worked with for years past, and never found to fail. All ships were not alike; some had enclosed stokeholds, some were poorly made, and the leakage was considerable. When he had that figure before him he had in his mind that they were

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dealing with new ships. With regard to the quantity which Mr. Oughterson imagined had been discharged by the 7-foot 6-inch fan, that gentleman omitted to mention the pressure. In the case he had given, the pressure should be 1¼ inch, and he did not think the discharge would then be more than 50,000 cubic feet. That was the result of a number of experiments he had made, extending over several years. Mr. Allen.

Correspondence.

Mr. E. A. COWPER found no reference in the Paper to the proper shape of a fan-casing. He would, therefore, beg to call attention to the fact that it ought to be an Arithmetical Spiral, as stated in his remarks on Mr. R. Briggs's Paper on Rotary Fans.[1] Mr. Cowper.

Mr. W. WARREN said the Author did not claim to have completely enumerated the many classes of auxiliary engines used on board ships, but had confined himself to those of which his firm made certain special types. Incidental reference, however, was made by Mr. Siemens and others to the use of electric motors for driving winches and the like. All were familiar with that most useful but imperfect machine, the winch, with its excessive waste of steam and its noisy spur-gearing—which latter was endured with a forbearance difficult to understand when it was remembered how differently these things were worked in America with almost noiseless friction-gear. Better than this, however, and what he particularly wanted to refer to, was the hydraulic system of working cargo, which besides being perfectly noiseless, enabled light or heavy goods to be handled much more rapidly than with steam-winches. This application of hydraulic power, apart from some difficulties in the use of it in very cold climates, was a perfectly ideal system, concentrating all the machinery into one place under the eye and control of the engineers. The new steamers of the British India Steam Navigation Company, the Messageries Maritimes, and a few others running to Australia and elsewhere, were all fitted with hydraulic cranes, with wire-ropes instead of chains, making all the movements so quietly that ordinary conversation could be carried on during cargo-working. Mr. Warren.

Mr. C. HUMPHREY WINGFIELD agreed with the Author as to the necessity for easy curves in the air-passages to and from the fans, but thought that the excessive loss of pressure referred to on Mr. Wingfield.

[1] Minutes of Proceedings Inst. C.E., vol. xxx. p. 297.

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Mr. Wingfield. pp. 15, 16, might have been partly due to the delivery-pipes being small. If the air-way through the firebars and coal was large as compared with the section of the fan delivery-pipe a considerable fall in pressure must ensue. Perhaps the Author would give his views as to the proper diameter of fan and of air-pipes for a given size of grate with a definite pressure of under-grate blast. He thought the Table in the appendix required some little explanation. For instance, how was the 5·5 "loss in engine, dynamo-shaft and bearings" arrived at? Was it measured directly by a dynamometer between the engine and the dynamo while the latter was in full work, or was it measured by friction cards, or otherwise, when the engine was unloaded? It was so remarkably constant that it looked as if some assumption had been made; being the same when the engine ran free as when it was indicating 56·97 HP., and this in a Table where the indicated horse-power was worked out to two decimal places! Professor Thurston had stated, as a result of some trials with non-condensing engines, that the horse-power per revolution wasted in friction by a given engine of this type was independent of the load. On the other hand some careful experiments by Walther-Meunier and Ludwig[1] showed the horse-power wasted per revolution by a condensing engine increased slowly with the load. Professor Thurston's results showed, therefore, that a friction-card taken when the engine was running free gave a true measure of the wasted horse-power at that speed whatever load might be afterwards put on. The other experiments showed the contrary to be the case. If the Author had tested this point it would be of great interest to hear his conclusions. He desired to ask whether 9·29 should not be put in the indicated horse-power column as well as in the fourth column, and 5·5 in the second line of horse-power column, as otherwise he could not understand how these quantities were arrived at. Perhaps the Author would also state whether in estimating the losses in the dynamos the figures represented merely the electrical horse-power due to the current passing through the shunt-coils, or whether the waste power which generated Foucault currents in the pole-pieces, &c., was estimated and allowed for. It would seem that this should be added to the figures for loss in the dynamo.

Mr. Allen. Mr. ALLEN stated, in reply to Mr. Warren's remarks, that while hydraulic arrangements had been improved and introduced into a number of vessels for some time past, instead of mechanical means

[1] Bulletin de la Soc. Ind. de Mulhouse, vol. lvii. p. 140.

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for raising, lowering, steering, and so on, it was clear that in the future electricity would supersede the former power. In answer to Mr. Wingfield, he was unable to deal briefly with the question as to the proper diameter of fans and air-pipes for a given size of grate, owing to the fact that every system required a different volume and pressure, but he hoped to collect particulars on this head later on. With regard to Mr. Wingfield's remarks upon the Table of efficiency, the 5·5 HP. (which was the loss in the bearings of the dynamo-shaft) was carefully calculated from several diagrams taken while the engine was running light, and with the brushes lifted from the machine; and it was assumed that the HP. wasted in friction was the same at full load or any part of the load. In answer to the question whether 9·29 HP. should not have been put in the Indicated HP. column as well as in the fourth column, the Author pointed out that the 9·29 HP. was entirely lost, and did not represent any useful work. It should be explained that the losses in the dynamo given in the third column, represented the whole power lost over the armature and field-magnets, and that it increased from light load to full load. Mr. Allen.

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20 January, 1891.

SIR JOHN COODE, K.C.M.G., President,
in the Chair.

The discussion upon the Paper by Mr. W. H. Allen, on "Auxiliary Engines in connection with the Modern Marine Engine," occupied the evening.

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LIST OF MODELS, &c.

EXHIBITED AT THE MONTHLY RECEPTION.

13 January, 1891.

Exhibitor.	Objects.
W. H. Allen, Assoc. M. Inst. C.E.	Centrifugal pump.
	Electrical gear for first-class cargo-steamers.
	Engine and dynamo.
	Single-inlet fan and engine.
W. Anderson, D.C.L., M. Inst. C.E.	Magazine rifle and component parts.
Sir W. G. Armstrong, Mitchell & Co.	Model of floating steam-crane at the Liverpool Docks.
Sir B. Baker, K.C.M.G., M. Inst. C.E.	Electric motor.
	Model of the Forth Bridge.
	Model of a steam ferry-boat.
Syd. W. Barnaby, M. Inst. C.E.	Model of first-class twin-screw torpedo-boat.
J. Wolfe Barry, M. Inst. C.E.	Model of the Barry Docks, Cardiff.
	Model of the Tower Bridge.
William Bashall, Assoc. M. Inst. C.E.	Case of samples of patent metallic packing for high-pressure engines.
Lord Brassey, K.C.B., Assoc. Inst. C.E.	Albums (four) of photographs of scenery in Australia and New Zealand.
Caird & Rayner	Evaporator for marine boilers.
J. G. Chandler, Assoc. M. Inst. C.E.	Set of models of beam-engine and pumping-plant.
Thos. Coates	Model of steam fire-engine.
Sir Jas. N. Douglas, M. Inst. C.E.	Electric lighthouse-lamp with pair of large fluted carbons.
	Set of Douglas lighthouse-burners, oil and gas.
	Small air-engine for rotating the lantern at St. Catherine's Lighthouse.
J. & E. Hall	Photographs of refrigerating machinery.
John Hastie & Co. . . .	Model of safety after-steering gear.
Higginson & Co.	Model of steam ash-hoist.
	Model of steam quarter-master (combined hand and steam steering-gear).
John Kirkaldy, Assoc. M. Inst. C.E.	"Compactum" Distiller.
	Drawing of fresh-water distilling and feed make-up machine on the S.S. "Lombardia" of the Royal Italian Navy.
	Drawing showing arrangement of heating and evaporating machinery in a mercantile steamer.
	Drawing of machine combining surface-condenser, feed-heater, and feed make-up as fitted to a triple-expansion engine.

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Exhibitor.	Objects.
V. DE MICHELE, Assoc. M. Inst. C.E.	Model of reversing-gear.
C. A. PARSONS & Co. . . .	Turbo-electric generator, with armature.
NAPIER PRENTICE	Armature.
	Power-motor.
	Magnetic cut-out and fuses.
E. S. PRESTON, Assoc. M. Inst. C.E.	Model of improved tail-board for tip-carts.
R. C. RAPIER, M. Inst. C.E. .	Model of sluices proposed to be erected on the River Thames at Richmond.
T. RICHARDSON & SONS . .	Model of Morison's No. 3 evaporator for marine boilers.
ERNEST SCOTT & MOUNTAIN .	Gun-metal casting of a fan-impeller.
	Model of magnetic-separator.
	Triple distilling feed-pump.
SIEBE, GORMAN & Co.. . .	Model of cold-air refrigerator and store.
JOHN I. THORNYCROFT & Co.	Model of guard-boat for defence of submarine mines.
	Model of shallow-draft patrol-steamer.
	Tubular boiler.
W. H. TOPHAM, Assoc. Inst. C.E.	Armstrong shell dug out of No. 3 dock at Buenos Ayres after the revolution.
FRANCIS WISWALL, Assoc. M. Inst. C.E.	Model of movable weir.
A. F. YARROW, M. Inst. C.E.	Model and photographs of sea-going torpedo-boat.
	Photograph of an Argentine first-class torpedo-boat.
	Photograph of second-class torpedo-boat.
	Photograph of gun-boat for service on the Zambesi.

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27 January, 1891.

SIR JOHN COODE, K.C.M.G., President,
in the Chair.

(*Paper No. 2491.*)

"Machine-Stoking."

By JOHN FREDERICK SPENCER, M. Inst. C.E.

STEAM engineering includes three distinct processes:—1. The combustion of fuel and the production of heat. 2. The generation of steam by transmission of the heat produced by combustion. 3. The disposal of the steam generated for motive- or heating-purposes. Except only in the references to evaporation-trials and efficiency, the present Paper is limited to the first of these, viz., the combustion of fuel and the production of heat.

It would not be in accordance with the purpose or the scope of this communication to discuss the chemical theory of combustion. The heat-unit values per lb. of fuel burnt to carbonic acid and carbonic oxide, 14,133 and 4,452 respectively, and the supply of air required for their formation, 141 and 76 cubic feet, are well known; and both in machine- and hand-stoking the conditions, which these figures give, have to be met in order to effect perfect combustion. Experience has proved that with hand-firing sometimes an amount of oxygen is found in the waste gases leaving the boiler flues, equal to the whole quantity required for the complete combustion of the fuel. Such excess of air-supply is due to the difficulty of mixing the carbon and the oxygen perfectly; and this difficulty is diminished by machine-stoking. The inequalities of hand-firing arise mainly from two causes, namely, admitting air at the wrong time and place, and adding fuel according to the pressure gauge, without regard to the requirements of perfect combustion. It may be admitted that with a uniform evaporative duty (such as exists in many mills under careful supervision, and in water-works, where there is competent engineering superintendence) the deficiencies of hand-firing may be lessened, but they cannot be removed.

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Machine-stokers are of two distinct types, called respectively coking- and sprinkler-stokers, both being supplied with coal from a hopper. In the coking-stoker the fuel is fed slowly on to the dead-plate, movable bars being provided for carrying it forward at a rate intended to be proportionate to that of the combustion required. In the sprinkling system the fuel is more or less evenly distributed on the grate by fans, beaters, or shovels, with or without movable bars. In both systems with moving bars it is claimed that when the fuel arrives at the forward end of the bars there is nothing left but ash and clinkers, which drop into a space provided for them, and from which they are removed through the ash-pit.

The Author proposes, after giving a brief sketch of the history of the subject, to describe at length one of the most successful machines of each type, selecting for the purpose the well-known coking-stoker of Messrs. T. and T. Vicars of Liverpool and Earlstown, and illustrating the sprinkler type by the equally well-known machine of Mr. E. Bennis of Bolton.

It is no matter of surprise that James Watt included a machine-stoker among his many inventions. The James Watt stoker of 1785 was worked by hand, and consisted of two sets of bars one behind the other, the fuel being fed at the door end, and pushed forwards as it ceased to smoke, the smoke from the fresh fuel passing over and through the more advanced combustion at the bridge-end of the grate. Mr. C. Wye Williams, referring to the original specification says, "these words of Watt, 'through, over, or among a body of hot, glowing coals,' have led more men astray, and occasioned more waste of money, loss of time, and misapplication of talent, than almost any other false light of the day."[1] Mr. Williams points out that as the air passing through the coke or glowing coal near the end of the bars is exhausted of its oxygen by contact with the hot fuel—which oxygen has combined with the carbon to form carbonic acid—the only possible effect of endeavouring to prevent smoke by this method, will be that some of the carbonic acid will be reduced to carbonic oxide by taking up a second charge of carbon, thus causing the loss of a considerable quantity of heat. It is, however, evident this loss cannot occur if, in the system condemned, provision is made for a supply of oxygen to meet the full demands of the carbon present in all stages of the combustion.

In 1816 Dowson invented a machine-stoker for feeding upwards by a piston, so as to keep a hot fire on the top. Some thirty

[1] "The Combustion of Coal and the Prevention of Smoke," by C. Wye Williams, 1854, p. 37.

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patents have been taken out on this system by Juckes, Beeby, Frisbie of New York, and others. Frisbie's method of feeding by three horizontal screens was the only one which was much used, and none of these inventions have been sufficiently successful for permanent adoption.

In 1822 the two systems of coking and sprinkling were applied, by Brunton and Stanley respectively, to externally-fired boilers. Brunton introduced both the pushers for feeding and the movable bars, and he has been followed by nearly 200 specifications for various modifications of the coking machine. Among these inventors were Juckes, in 1841, and Bodmin, in 1843; the Juckes stoker being well known and largely introduced. The coal was fed from a hopper on to a moving chain-grate, the feed being regulated by a drop-shutter. It was only suitable for under-fired boilers, was deficient in power, not economical, and the maintenance was costly, but it was efficient as a smoke-preventer. The attempt by Taylor and others in 1873–4 to adapt this stoker to Lancashire boilers was not successful.

In 1866 and 1869 Howarth and Horsfall invented a coking-stoker with hollow fire-bars, fed with water from the boiler. The bars were stationary, and the coal was carried along by a saw worked by an eccentric; but frequent leakage led to its failure, although it was successful when in working order.

Brunton's system was meanwhile being modified in many important particulars by Normand in 1856; Wilson and Smith 1863; Vicars and Smith in 1867, 1868. In 1879 and 1889 Messrs. T. and T. Vicars introduced their most recent improvements in the coking-stoker.

To complete this brief historical record of machine-stoking it is necessary to return to the year 1822, when the sprinkler-stoker was introduced by John Stanley, his drawing representing the machine as applied to the wagon-boiler. The fuel from the hopper was thrown on the fire by three beaters or vanes fixed on a revolving shaft, and working in a case under the hopper. These stokers were fitted to many furnaces, and various modifications were made by Church, W. and J. Galloway, Robert Newton, Rye and others. As in the case of the coking-stokers, the change from external to internal-firing operated against the success of the sprinkling system. In 1870 an American named Dilwyn Smith, in Liverpool, although not an inventor or mechanic, saw the advantages of machine-stoking, and having obtained the aid of Mr. G. F. Deacon, M. Inst. C.E., Mr. Thomas Henderson, well known as a maker of sprinkler-stokers, and Mr. Edward Bennis,

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the inventor and maker of the machine of that type selected for this Paper, succeeded in 1872–4, in producing an adaptation of the Stanley stoker to the Lancashire and Cornish boilers, which was fairly successful, although somewhat costly, and not fitted with movable bars.

During the introduction of the Dilwyn Smith stoker, Mr. Bennis made a series of tests at the works of Messrs. Jackson Brothers, Wharf Foundry, Bolton, with a view to ascertain the advantages of combining the movable bars with the sprinkling system. Mr. C. Wye Williams had expressed the view that an even distribution of fuel, allowing free mixing of the air, combined with a self-cleansing bar, would produce the most perfect system of combustion that could be realized. At this stage of the progress of the sprinkling system many of its advocates, and notably Mr. Bennis, held this view, and believed that the sprinkler-stoker was specially adapted to cases where there was a deficiency in evaporative duty. Mr. Bennis's experiments in 1874 confirmed the advantage of the movable bars, and also led to one of the special features of his machines, namely the distribution of the fuel over different portions of the fire-grate in succession. This was included in his specification dated April 1875, and in June of the same year Mr. Proctor claimed certain special mechanism for varying the distribution. A costly litigation ensued, and both inventors are now actively manufacturing machine-stokers very similar in character as to distribution of the fuel, but differing in the important items of the movable bars and the disposal of the clinkers and ashes.

In consequence of the more active combustion in the sprinkling, as compared with the coking system, there arose a greater necessity for protecting the movable bars from the intense heat, and in cases where this protection has not been secured, the wear has been severe. Mr. Bennis claims to have succeeded in combining with the sprinkler-stoker a system of movable bars that can be regulated to suit any rate of combustion. Mr. Bennis also provides a supply of steam underneath and in front of the dead-plate by means of a $\frac{1}{4}$-inch or $\frac{3}{8}$-inch pipe, perforated with holes $\frac{1}{32}$ inch in diameter, and so drilled that jets of steam and air are blown along and between the line of fire-bars; the effect of this minute expenditure of steam being to prevent the adhesion of clinker to the bars, and also, according to the inventor, to act as an aid to combustion.

Mr. Proctor has introduced various improvements in sprinkler-stokers since 1875, and one firm has forty-six furnaces fitted with his machines.

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COKING-STOKERS. (ILLUSTRATED BY THE VICARS MACHINE-STOKER.)

Figs. 1, 2 and 3, Plate 2, show the new and improved mechanical stoker and smokeless furnaces of Messrs. T. and T. Vicars, applied to a Lancashire boiler 28 feet long, 7 feet 6 inches diameter, having two flues each 2 feet 9 inches diameter. Small bituminous fuel is deposited in the large hopper shown in Fig. 1, and by its own weight falls into four boxes—two for each furnace—from whence it is gradually pushed into the fire-places, by alternately reciprocating plungers (Fig. 3), falling first on to a perforated dead plate 12 inches long, where it ignites, and thence on to the fire-bars. Each plunger receives its motion from a bell-crank lever connected with an eccentric and a strap, deriving its movement from the cam-shaft. This shaft, with its necessary fittings, is shown in Fig. 2. The hopper for this size of boiler will hold from 10 cwt. to 12 cwt.

The bars have a peculiar reciprocating motion, being moved slowly forward simultaneously, but returning in two sections. Figs. 4 show how the connection is made between the bar and dog-shaft for each furnace. These connecting pieces are technically called upper and lower keys, and transmit a reciprocating movement from the dog-shaft to the bars. Here one set of the bars, namely those attached to the leading or upper key, is seen to be drawn away from the end of the grate to the maximum distance, viz., 4 inches. The alternate bars have a low seat in front as shown in Fig. 4, *c*, resting upon a lower cross-bearer attached to the lower keys, and the latter, having just been respectively released by a heart-shaped cam from their resisting pawl (which is provided to prevent the lower keys from coming forward with their bars before the due time), are about to be drawn away from the end of the grate also, the same maximum distance, viz., 4 inches. Thus the bars receive their alternate motion. There are two hardened-steel dogs, and one heart-cam connected with each set of keys, and two sets of keys to each furnace or flue.

The bars having been brought backward, as shown in Fig. 1, and the cam-shaft having continued its intermittent motion, the leading dogs are brought into contact with the stroke-bar, Fig. 4, *b*. The positions of the other dogs at this point are seen on the left (Fig. 4, *a*); they do no actual work during the forward movement of the bars—and so, against the resistance of the stroke-bar pawl, which is attached to the upper

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keys, the latter are pushed forward, and they drive before them the whole of the bars. The low-seated bars receiving this motion at the same time from the cross-bearer of the top bars, shown in Fig. 1, draw their connected keys after them, the latter conveniently sliding over their resisting pawls, which act only in the backward stroke of the top bars and upper keys. In this way the burning mass of fuel is gradually but slowly carried forwards.

Such unconsumed fuel as reaches the end of the fire-bars, is discharged, together with the clinker and ash refuse, into the flue, wherein a bank is thus formed acting as a bridge to close the end of the ash-pit, and on which the combustion of the precipitated fuel is in due course completed, Fig. 1. The clinker and ash are removed from the combustible matter at the back, and drawn out from underneath at intervals varying from three to twenty-four hours according to the quality and quantity of coal consumed, no opening of the fire-door being necessary for this cleaning; sufficient, however, is left in the back, or on the bottom of the flue to form a close bank against the admission of cold air through the bars and into the combination chamber (Fig. 1). A small quantity of steam is allowed to blow upon the end of the bars from a jet, and tends to keep them and the bearers cool.

The supply of fuel is regulated with facility by a simple mechanical arrangement (Fig. 2), consisting of a quadrant and clicks. The stroke or travel of the bars may be adjusted to any length less than 4 inches, by altering the position of the stroke-bar from that shown in Fig. 4, and pushing it inwards. When the resisting click is in the first tooth of the draw-bar, the part for contact with the dog falls outside the circle of motion made by the latter, and this being so the bars remain at rest; but between these two positions they may be made to move, and the fuel fed, according to the work required from the boiler. The formation of clinker is prevented by this method of moving back alternate bars at the same time, and the admission of air under them is also rendered uniform. The whole machine stands on strong girders bedded on the ground, which relieve the front plate of the boiler from any strain.

The driving-power is supplied by a shaft which may be placed either above or below the stoker, and on which are fixed two eccentrics, each actuating a ratchet-wheel and pawl, Fig. 2, and thus communicating to the dog-shaft the intermittent motion referred to. The eccentrics on the driving-shaft are so fixed that the latter does not bear the strain of the whole machine at any one

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time, one dog-shaft being at work while the other is at rest, so that the boiler has a constant supply of fuel. Hand-firing may be easily resorted to by opening the large door between the plungers (Fig. 2).

The driving-shaft has a constant rate of from 18 to 20 revolutions per minute, and the dog-shaft being regulated entirely by the arrangement already referred to, can be made to revolve at any speed up to 3 or 4 revolutions per minute, and needs little or no lubrication. Smoke is entirely prevented, inasmuch as no coal is allowed to pass on to the bars without first mixing with the perfect combustion already going on, and any smoke resulting from the mouth of the fire is completely consumed before it has left the grate.

Sprinkler-Stokers. (Illustrated by the Bennis Machine.)

In this arrangement, as applied to the ordinary Lancashire boiler, a hopper is placed directly above the centre of each furnace, so as to leave room for glass water-gauges and steam-gauge between them, and so that each fire may be independent of the other. Underneath this hopper is a throwing apparatus or stoker, consisting of a cast-iron box B, with a shelf C inside. On this shelf a pusher-plate D slides, being actuated by the lever L, which receives its motion from the scroll-cam H.

The scroll-cam is made in two parts, so that it may be closed or opened by hand-nuts on the long end. The effect of this arrangement is, that the motion of the pusher-plate D can be exactly regulated, and the fuel at each stroke measured with great accuracy. The pusher-plate D, being drawn back by the lever L, as much fuel falls in front of it as fills up the blank space left by its withdrawal; it then moves forward again, the coal being propelled before it so as to fall over the edge of the shelf C, in front of the shovel S, ready to be thrown on the fire.

The throwing-apparatus consists of a V-shaped shovel S, resting on the bottom of a cast-iron box B. This shovel S is hinged to the lever or shovel-arm M, which latter is screwed on to the side of the box, so as to obtain sufficient length of stroke without making the shovel deep. On the side of the shovel-arm is a projection against which the tappet T presses so as to draw back the shovel-arm and shovel, against the pressure of the throwing-spring P. It will be seen that in Fig. 6 it is drawn under the shelf C right away from the fuel. As the tappet releases the arm M, it darts forward, and the shovel S strikes against the

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heap of fuel, scattering it over the fire with more or less force according to the distance to which it has been previously drawn back.

The tappet T is made with four different-sized lifts, so that in one revolution of the shaft O four throws of varying strength will be given. These throws are so adjusted that the first sends the fuel on to the front part of the bars near the fire-door; while the next charge is thrown nearly to the end of the bars, and is scattered all across the fire over a space about 2 feet in length; the third throw distributes the fuel just beyond the first, and the fourth beyond that again. The object of this particular arrangement is to give time for the consumption of the suddenly liberated hydro-carbons before a fresh charge of fuel is added, thus preventing smoke, and producing perfect combustion.

Projecting from the shovel-arm M is the short lever F, to the end of which is attached a hardened steel pin G. Two springs work on this pin, being attached at their farthest end to rocking wing-nuts with hardened ends. When the tappet T lifts the shovel-arm M, the lower spring is drawn into tension, and the top spring is practically free from load. On the tappet releasing the shovel-arm, the latter bounds forward and reverses this position, coming almost at once to the point of rest. This arrangement gives perfect control over the distribution of the fuel, as by a turn of the wing-nut, the tension of the driving-spring may be sufficiently increased to throw the coal 1 foot or 2 feet further. Below each stoker is a fire-door A, usually 10 inches deep and 16 inches wide, so as to afford ample space for stoking by hand at night. This door is constructed to admit a small quantity of air, which passing through a perforated plate, is forced over a second plate, and then down close to the fire, where it discharges itself in small streams through a grid, keeping the outside of the door quite cool.

In the Bennis Camel-Furnace (Plate 2, Fig. 6), the fire-bars are usually about 5 feet long from the dead-plate to the end. At the front there is a depression about 3 inches deep, and then a slope 12 inches long and rising 3 inches. Beyond this the upward slope is only about 1 in 48, but at the farther end of the bars it increases to 1 in 6. Thus the end of the fire-bar is much higher than the front, and the clinkers and ashes have to ascend this hill to the clinker-chamber, in which they lie until all their heat is given up and they are drawn out dark and cold. This movement of the fuel is effected by the whole of the bars being pushed forward a distance of 1½ inch by the pressure against

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the bottom projection on the bar U of the cam-bar E, and by the washer-cams W (which are strung upon it, and are set at slightly varying points) bearing against the top projection on the bar at I. The bars are brought back to the front in series, so that only one in eight returns at the same time, leaving the clinker and fire 1½ inch further forward for each complete revolution of the cam-shaft. The non-production of smoke is secured in this arrangement by the varying throw, combined with a continually clean fire; the supply of fuel being adjusted to the draught, so that the highest results as to production of steam and economy of fuel are secured.

An important point in stoking apparatus is wear and tear, and in this machine the minimum is secured, as follows:—The gearing bracket Z, Fig. 5, Plate 3, is enclosed in covers to prevent dirt and dust reaching the bearings, and all the working parts therein run in oil. All the cams, tappets, and other wearing parts are deeply chilled, and the wearing part on the shovel-arm is of hardened shear-steel.

When machine-stokers are fitted with hoppers filled by hand the only labour saved as compared with hand-firing is that of slicing and raking the fires; but where there are several boilers in a range a more important economy can be effected by raising the coal with a Jacob's ladder or elevator, and then conveying it in an overhead trough by a screw or tray-chain to each hopper as required (Fig. 7). The elevators and conveying-screw are driven from an over-head shaft, which may be the one used for driving the machine-stokers. In some cases this conveying-plant is also employed for removing the ashes and clinkers.

In many machine-stokers a crushing-mill was formerly placed under the hopper and over the feeding gear, to allow large coal to be used, but this provision is now seldom introduced, preference being given to the smaller and cheaper coals which possess good calorific value but are not available for hand-firing without loss of evaporative duty. If, however, machine-stoking should be more generally adopted, it might be found necessary to have this crushing-gear either in the machine or at the collieries.

Machine-stokers are generally worked by a small engine. For this purpose a 6-inch cylinder is ample for a range of twelve 7-foot Lancashire boilers, and estimating the average coal consumption for these boilers at 60 cwt. per hour, the fuel required for driving the machine-stoker would not exceed ½ cwt. per hour. To this must be added the loss of steam in the grate-jets. By a careful experiment made by Mr. Bennis, in 1882, it was

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found that at 82 lbs. pressure the weight of steam escaping through sixteen holes each $\frac{1}{32}$-inch in diameter was 35 lbs. per hour. Supposing that these steam-jets only served to keep the bars clean and cool, there would be a charge on the boiler fuel of about 2 per cent., but experience has proved that a higher duty can be realized with than without the jets.

The advocates of machine-stoking contend that the following advantages result from its adoption:—(1) Prevention of smoke; (2) Economy of fuel; (3) Increased and more uniform evaporative duty; (4) Economy of labour, when combined with conveying plant.

1. *Prevention of Smoke.*—With the certain prospect of more strict legislature to reduce the smoke nuisance, its abatement is of great importance to the steam-user and the public. It is generally held that to prevent the emission of hydro-carbons in smoke, there must be on the same grate a green and a hot fire, a rapid and a slow combustion. With hand-firing this is only possible by keeping an intense fire near the bridge and a green fire near the dead-plate, or by the "alternate-side firing" system advocated by Mr. C. Wye Williams. There is also a great tendency to rely on the deficient supply of air being rectified by the split-bridge. It has been stated that it is not necessary to have machine-stoking to prevent smoke, as it can be sufficiently reduced by careful hand-firing. This statement is possibly true as applied to cases where there is specially intelligent supervision, but it is untrue as regards average steam-users and their stokers. Nor is the split-bridge a reliable remedy, unless the extent of air-admission can work in harmony with the stoking. It is true that Mr. Parkinson's application of the split-bridge has, when fairly tried, greatly reduced the emission of smoke; but this success is not independent of "careful hand-firing." The great advantage claimed for a machine-stoker as a smoke-preventer, is that it is always working under Mr. C. Wye Williams' essential conditions of a green and a bright fire on the same grate, much better localized than with "alternate-side firing," when it is quite possible for the gases to escape on the green side without combining with the oxygen on the hot side. With movable bars, machine-stoking is something more than a greatly improved system of combustion tending to smoke-prevention. It is an efficient remedy for smoke-pollution, and is the only system not dependent on that *rara avis* an educated stoker. Finally, with machine-stoking, one great cause of smoke in hand-firing is generally absent, namely, the frequent use of the slice and poker to rouse

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the fire and to clean the bars. An observer outside a mill where the boilers are hand-fired, can count the firing and stoking times by the emission of smoke from the shaft. In machine-stoking it is only at long intervals that the door is opened, and then for a much shorter time.

2. *Economy of Fuel.*—With reference to the economy due to the use of a cheaper coal in machine-stoking than is possible with hand-firing, the testimony is overwhelming, and is rarely contested; but it is not so generally known that, owing to the more perfect combustion in machine-stoking, the cheaper coal often realizes also a higher evaporative duty per lb. of fuel.

In June, 1890, two careful trials of ten hours each were made at the Royal Paper Mills, Wandsworth, on a Lancashire boiler 7 feet 5 inches in diameter, and 30 feet long, with two 2-foot 9-inch flues, with the following results :—

——	Hand-Fired.	Vicars Machine Stoker.
Grate-area	33 square feet	22 square feet.
Quality of coal (small)	Welsh	Bituminous
Price per ton	15*s.*	13*s.*
Coal per hour	6·4 cwt.	5·3 cwt.
Water per hour	502 gallons	533 gallons.
Water per lb. coal	7 lbs.	8·98 lbs.
Cost per 1,000 gallons evaporated . . .	9*s.* 4·75*d.*	6*s.* 5·5*d.*

The fact that three firms alone have between them, either working or on order, 340 coking-stokers is strong evidence in favour of machine-stoking.

The testimony in favour of sprinkler-stokers is equally satisfactory, as is shown by the following trials of Bennis stokers, one made under the direction of Mr. L. E. Fletcher, M. Inst. C.E., and the other under the direction of the Author.

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Messrs. ARMITAGE and RIGBY, Warrington.

Date, June and July, 1888.
Boiler, Lancashire, 7 feet by 27 feet; two 2-foot 9-inch flues.
Working pressure, 75 lbs. per square inch.
Temperature of feed-water, 55°.

	Hand-Firing.	Machine-Stoking.
Duration of trial	56 hours	35 hours
Coal consumed per hour	730 lbs.	917 lbs.
Water consumed per hour	450 gallons	677 gallons
Water evaporated per lb. of coal	6·18 lbs.	7·37 lbs.
Coal used (slack) 4*s.* 6*d.* to 5*s.* 7*d.* per ton	..	..

There was a second trial on June 18th and 19th with almost identical results. Mr. L. E. Fletcher, in his report to Messrs. Armitage and Rigby, concludes in these words:—"It is clear that in these trials the mechanical-firing had a decided advantage as compared with hand-firing, the duty obtained from the boiler with it being much higher, the water evaporated per lb. of coal much greater, and this with fuel lower in price."

The other competitive test with hand-firing was at the Middlesex Hospital, on a boiler of marine type, with one 2-foot 9-inch furnace-tube. To meet the demand for greater heating-power a Bennis stoker was ordered by the Author on the advice of the late Mr. Inglis, M. Inst. C.E., of Bolton, and previously to its being fitted, several careful hand-fired evaporative trials were made in September, 1889, with best large Welsh coal, the maximum duty realized being 195 gallons per hour, and 7·622 lbs. of water per lb. of coal—a poor result, due chiefly to heavy firing and deficient air-supply and draught. After the sprinkler-stoker was fitted a number of tests were made, with the following results:—

	Water Evaporated		Temperature of Feed.	Quality of Coal
	Per Hour.	Per lb. of Coal.		
1889.				
October 25	310 gallons	8·38	206°	Welsh small and small rough Hartley.
November 1	284 „	9·71	186°	Welsh small.
October 31	190 „	10·178	193°	„ „

The test on the 31st of October was in order to ascertain the consumption of fuel with the same evaporative duty as when hand-fired. With hand-firing the speed of air in the ash-pit, as measured

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by an anemometer, was 400 feet per minute; but with the stoker it was 750 feet. It is a general result of machine-stoking to largely increase the supply of air, and this may be partly due to the disturbance of the fuel by the movable bars and the absence of a thick fire.

3. *An increased and more uniform Evaporative Duty.*—The Author considers that greater evaporative duty may be expected with sprinkler- than with coking-stokers, the coking system having been chiefly adopted where the boiler-power is ample. There are cases, however, as at the Southwark and Vauxhall Waterworks at Hampton, where a Vicars' stoker consumes nearly 30 lbs. of coal per square foot of grate-surface. The automatic supply and progression of the fuel gives great uniformity of evaporation.

4. *Economy of Labour.*—This may be and is realized by machine-stoking, as the system permits the automatic supply of fuel to the hoppers. Mr. Campbell, of Perth, informed the Author that in a range of eight boilers with conveyors, one man had been saved.

In the mercantile steam navy machine-stoking is hardly known, only a few vessels being fitted with Henderson's movable self-cleansing fire-bars. It would save the loss of cleaning fires, and give a larger increase of evaporative duty than forced combustion by fans, and with much less injury and inconvenience. An increased duty of at least 10 per cent. from a ton of coal might be obtained with the employment of less highly-skilled labour. In addition to these advantages, all classes of cheap coal would be available for steam-ships, and smoke would be prevented—a great boon for the passenger traffic.

The number of furnaces fitted with machine-stokers and working at the present time is approximately as follows:—

Coking-Stokers.		
Juckes and others, old style	300	
Vicars	2,500	
Sinclair, McDougall, and others	600	
Frisbie, Beeby, and others	200	
		3,600
Fan and Spring Sprinkler-Stokers.		
Stanley beater, or fan machines	20	
Dillwyn Smith and Henderson	1,500	
Whittaker, Hodgkinson, Carver Newton, Rye, Leech, and others	1,000	
Bennis	5,000	
Proctor	4,000	
		11,520
Total		15,120

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This would represent about 8,000 boilers out of an estimated total in the United Kingdom at the present time of 140,000, or only 5·7 per cent. fitted with machine-stokers, and it has taken nearly seventy years to achieve this limited success. It is estimated that out of the 140,000 boilers in the United Kingdom, about one-half are to be found in the three counties of Lancashire, Yorkshire and Cheshire, and about the same number—70,000—are under inspection by the Manchester Steam-Users Association and the several Boiler Insurance Companies. Possibly, if statistics could be obtained of the percentage of boilers working at the present approved high pressure, or of the percentage of compound or triple-expansion stationary engines, the result would be somewhat analogous to that of the stokers. In two large Boiler-Guarantee and Insurance Associations there are approximately 1,010 boilers fitted with machine-stokers, or about 8 per cent. of the total number under the inspection of these associations.

The tendency of all boiler-inspection is highly conservative, its chief aim being to ensure safety, and in some cases, good dividends. Its best work is repetitive, and that is opposed to progress and improvement, so that both in reports and circulars it is necessary to remember this and read between the lines. Machine-stokers are suffered, but not recommended, and this alone has affected them adversely.

The Paper is accompanied by the drawings from which Plates 2 and 3 have been prepared.

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Discussion.

Mr. Cowper. Mr. E. A. COWPER did not think the Author had given as much credit to mechanical stokers as they deserved, but on the contrary had been rather modest in claiming their advantages. To show that, he would take the case of steam-boilers in London, as local circumstances often greatly affected the proper treatment of steam-power. He made a great many experiments about fifty years ago on a steam-boiler with and without forced draught, using several kinds of American anthracite, as well as different sorts of English coal. He found that with a few alterations in the furnace, narrower bars, and a change to a cheaper fuel, namely, "Leases Main" in place of Hartley, he saved one-third of the total cost, and that without using forced draught. He tried letting in steam (perhaps in rather too great a quantity); but the general effect was to shift the heat, so to speak, further along the flue, in consequence of the production of hydrogen and carbonic oxide from the action of the water on the fuel and the subsequent burning of those gases some 6 or 8 feet further on. That had the effect, to a certain extent, of consuming the smoke, not necessarily by preventing the formation of it, but by giving a higher temperature at the particular point where they wanted the hydrocarbons to burn. He thought it was very likely that the small jets of steam now introduced were not extravagant, and answered the purpose sufficiently well. Since that time he had made numbers of boilers, and found that when the air-admission was properly arranged, a little care in the stoking, namely, putting the fresh coal on the dead-plate and front of the fire, and then pushing it forward from time to time, would practically prevent smoke if the draught was properly regulated. He always admitted a certain quantity of air per square foot of grate when the boiler was not required to be forced, and in order to increase the supply of steam he let in a little more air by putting a screw through the fire-door, so that it would not shut within a $\frac{1}{2}$ inch or $\frac{3}{4}$ inch. That was a rough-and-ready means of preventing smoke. In Liverpool and some other places they said the best plan was to give the stoker sixpence a week extra at the end of the quarter if no complaint had been made of smoke during that time. That was found to be a very successful remedy. He had a number of Vicars' stokers

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at work in and about London, and they answered well on the whole, although, of course, there was a certain amount of wear and tear, as was the case with all machines working in the dirt. In arranging a mechanical stoker inside the tube of a boiler, it was advisable to line the bottom half of the tube for a short distance with curved bricks, forming an incline sloping down forward into the ashpit, so that any live coal that fell over the end of the bars might lie on the brickwork, and not on the bottom plates of the tube, which might be injured by it. He wished to call particular attention to the fact that in London people insisted on having their coal screened, and refused to take small coal and dust, which was consequently a drug in the market. It could be got at from 9*s.* 6*d.* to 11*s.* per ton, and with a good mechanical stoker would burn quite as well as coal at 20*s.* or 21*s.*, which meant that they got the fuel at half price. The result was that the cost of power, with a good high-pressure expansive condensing-engine, from a farthing per HP. per hour with large coal was reduced in many cases to half a farthing per HP. per hour with small coal. He had an early opportunity of handling one of the Bennis stokers and of observing how it could be adjusted so as to make it throw the coal to a distance of three, four, five or six feet if they wished it. The saving in cost of fuel in places where large coal was dear and small coal was cheap, was so great that he wished much more attention was given to the matter in London. In some localities where it would be necessary to break up the coal in order to get it small, the economy would not be so great. As to the saving in labour, it was necessary to put up lifting-apparatus and conveying-apparatus in order to deliver the coal just where it was wanted into the hoppers. He might add that it was very dangerous work for men to throw coal up to a high level, as it strained them, and often produced rupture. Mr. Cowper.

Mr. E. N. Henwood said the plan of firing boilers by the mechanical stoker was no doubt very clever, but in his opinion the use of liquid fuel would altogether put coal out of the market. He had a vessel fitted on his plan. The fuel was either a residue from coal or gas-tar, known as creasote or green-oil, or *astatki*, the residue from crude Russian petroleum. The evaporation derived from that boiler working at 60 lbs. pressure was over 30 lbs. per lb. of fuel. He also fitted it, in 1887, to a steam yacht of his own, the "Ruby," which was running for several months on the Thames, and was viewed by a great number of people including a representative from Lloyd's, from the Admiralty, the Board of Trade Surveyor, and other gentlemen. There was no trace whatever of smoke on any Mr. Henwood.

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Mr. Henwood. occasion, and no stoker was required. In the Caspian and the Black Seas several vessels had been running with liquid fuel.

Professor Kennedy. Professor ALEXANDER B. W. KENNEDY remarked that further information was desirable on one or two points. The matter of the economy of fuel in the use of a machine-stoker was of the first importance. In all the illustrations given, with one exception very poor fuel was used. In that one case, with good Welsh coal they got on the whole a very fair evaporation, but nothing remarkable or more than could be obtained with ordinary stoking. In the other instances poor coal was used, so that they were brought back to the point which Mr. Cowper had emphasised, and which was of great importance, viz., that it was perhaps possible by the use of machine-stokers to get smokeless combustion with a much cheaper fuel than would otherwise be used. Obviously, if the poor fuel was only half the price of Welsh coal, and if it could be made to do the same work with equal absence of smoke and with only an increase of 50 per cent. in weight, it was cheaper to use it. He should like to know a little more on that point, and also the actual value of the fuel employed in the particular experiment cited. With regard to the small steam-jet used both with the Vicars and with the Bennis stokers, he had not himself made measurements of either, but any one who had had experience of the use of steam-jets in furnaces would know that they were apt to be a serious snare. A small hole in a boiler with 120 lbs. pressure in it got rid of a large amount of steam. He did not mean to say that the figures given in the Paper were not quite right in this particular case, but he had been the means of disappointing so many gentlemen who had systems involving the use of steam-jets, by insisting on the measurement of the steam used in them, that he thought it only fair to say a word about it. Any one who had works or stations of any kind in London, was obliged to use some means for preventing smoke, whether he got a good economy out of it or not. In his own case, at an electric-lighting station not very far distant, he was at present simply using good Welsh coal and good hand-stoking. They did not get any smoke, and the economy was as great as could be obtained under similar conditions from the boiler, under any system of firing. Perhaps some one could state whether these machine-stokers were adaptable to the case of work which was varied quickly. Every one knew that if a fog came on, a London electric lighting station might have its load increased four- or five-fold in ten minutes. He would like to know to what extent they could rapidly work

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up the combustion in one of those boilers, or reduce it again if required. He did not know whether the economy of labour alluded to was a misprint, but surely it must be something more than the Author had stated when he said that Mr. Campbell, of Perth, in a range of eight boilers saved one stoker. If that was all, the saving was very small. In cases where he had tested boilers and stokers of that kind and obtained thoroughly good results, he had not found that the amount of air used differed much from that required with good hand-stoking, nor that the composition of the furnace gases taken from the chimney was very different. The Author very properly hinted that there were a good many small places where stoking was carelessly done in which the advantages of machine-stoking might possibly be obtained. With reference to a remark made by the last speaker as to the evaporation due to oil, he believed the figure he mentioned was 40 or 50 per cent. in excess even of the theoretical value of most oils. Professor Kennedy.

Mr. W. Linton Eskrigge was in a position to answer the question as to the power of the stoking machine to raise steam quickly, and to let it down when it was not required. A manufactory in Lancashire with which he was connected had sixteen sprinkler-stokers at work, and he could therefore speak from practical experience. They had adopted a regulator which acted in the following way. The damper being wide open, the steam gradually rose, either because of the firing, or because some portion of the work was shut off, until at last the pressure reached the desired amount, usually 100 lbs., and lifted the small safety valve A. When this occurred, the escaping steam acted with the full pressure in the boiler on the column of water contained in the pipe BB, and raised the bellows CC, thereby partially closing the damper DD, and at the same time throwing the belt driving the machine stoker on to the loose pulley, and stopping the steam-jets under the bars. As soon as the pressure fell to 100 lbs., or just under, the weight E opened the damper, started the stoker, and turned on the steam-jets. This action was so sudden and complete that as much as one-third of the work was often thrown off without causing the steam-pressure to vary more than 2 or 3 lbs. In that way a regular pressure was maintained, which, as practical people knew, was of great importance in cotton-spinning. The stokers were all of the same type, and the automatic action of the regulator was perfect. As an old member of the Stockport Corporation, he might state that for twenty or thirty years they had a sub-committee formed from the Mr Eskrigge.

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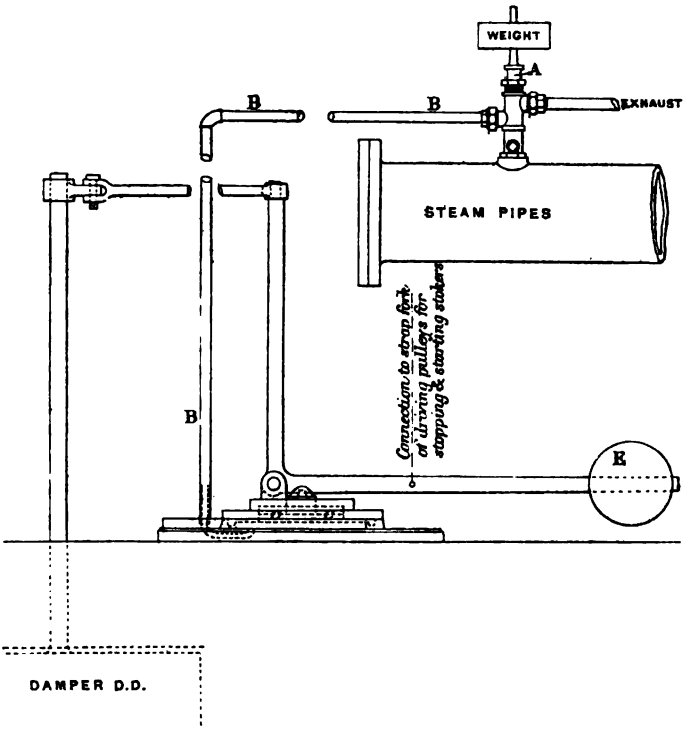
Mr. Eskrigge. Nuisance Committee to take the smoke question in hand. A Bill was passed by which they were not allowed to make more than ten minutes of dense smoke. When he became a member of a Cotton-spinning Company, having to put in new boilers, the Directors decided to try if it were possible, by fitting them with automatic stokers to make a practically smokeless chimney. After much consideration they fixed upon the "sprinkler-stoker" as

Fig. 1.



being the best. The Medical Officer of Health, who supported this decision, watched the chimney for some weeks, and not seeing any smoke issuing therefrom, came to the conclusion that the "works" must be stopped, and wrote to ask the reason why. With regard to another case in which the machine-stoker was applied in the town, the inspector gave up visiting the factory, as there was no smoke. They had gone to great expense in this matter of smoke-consumption, and having first put in eight

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stokers, they had now added eight more. With regard to the economy of fuel effected, in October, 1877, they were using 88 tons of coal per week, and they reduced the consumption to 76 tons of common slack, which to-day was worth 7*s.* 10½*d.* At that time it was worth 5*s.* 10½*d.* Mr. Eskrigge.

Mr. E. BENNIS said machine-stokers on the sprinkler system produced more steam per minute than any hand-firing in the world. If the self-cleaning bars were efficient, the moment each charge of fuel was thrown on, it burst into flame; in fact, the fire-box was continually full of flame. The steam-regulator made by his firm, to which Mr. Eskrigge had referred, acted partially by closing the damper, and entirely stopping the machine-stoker as soon as the small safety-valve was lifted; the damper being only left sufficiently open to keep the fire up. Taking 80 lbs. as a common pressure in Lancashire, as soon as the steam rose above 80, the damper was nearly closed and the machine stopped. As soon as it fell, say to 79½, the work would begin again automatically, and the fire being red all over, directly the new fuel fell on it, the flame burst out with great vigour. Where steam was taken irregularly, the apparatus would keep stopping and starting again; but where the demand was more regular it would run for perhaps half-an-hour, then stop for a short time, and go on again. Cotton mills seldom threw off at any one time above 7½ per cent. of the power employed, and in them the steam-pressure could be kept from varying more than ¼ lb. In some works, however, they put on or off 40 per cent. of the entire power, but even with this variation in the demand the pressure could generally be kept within about 3 lbs. Supposing that at such a factory the boiler-pressure were 80 lbs., they would set the regulator to 77 lbs., and rarely indeed would any steam blow to waste. It was most important that the regulator should be connected with the stoker as well as the damper, in order to keep the steam steady. His own machine was a shovel-stoker, throwing the fuel on the fire in consecutive zones; but it was open to him to make coking stokers as well. The reason he had not done so was, because the boilers in Lancashire, Yorkshire and Scotland were generally heavily fired. In London the practice was to have a good many boilers, and to fire them more easily. With the Bennis stoker on an ordinary-sized grate, 56 lbs. of small coal per square foot of grate per hour was being consumed night and day. When he first went into the business of machine-stoking, it was considered that a furnace which consumed 20 to 23 lbs. per square foot of grate per hour was doing very well. He was now testing hand- and machine- Mr. Bennis.

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Mr. Bennis. firing at one of the most important steel-works in Scotland, where by putting three men to fire one boiler, they burned nearly 50 lbs. of fuel per square foot of grate per hour.[1] He had guaranteed to beat the evaporation by hand-stoking by 30 per cent. with his machine. An important point in machine-stoking was whether the machine could burn the same class of small fuel, largely in use in the north for hand-firing, with economical results. This was what they had to do in Lancashire. In London machine-stokers were highly favoured because the users could buy the best fuel in the country, viz., small north-country coal, at half the price of good Welsh coal. Again and again, with small north-country coal, he had equalled or beaten the results obtained by hand-firing with best Welsh coal, thus saving the whole difference in cost. He could not do this in every instance, because the journey from Newcastle deteriorated the small fuel, and sometimes it had been lying in the yard for a considerable time. But whenever they got the small north-country coal fresh, they were able to obtain as good results by using it with the machine, as hand-firing would give with the best Welsh coal. Welsh large coal did not deteriorate quite so fast; but in London hand-firing had not done as well ton for ton or hour for hour with it as his machine-stoker had with north-country small fuel. It had been stated in the discussion that nearly all the tests had been made at low evaporation per lb. of fuel. That was necessarily so, because nearly every one who adopted stokers used common small coal. He had a case at Mr. Rich's mills at Stroud where 11 lbs. of water was evaporated per lb. of fuel by hand-firing, and 12¼ lbs. per lb. of the same class of small-coal with the machine-stoker, showing that the machine would do more work with the same fuel than hand-stoking. The same remark would apply to a properly run coking-stoker as to economy, but not as to increased production of steam per hour. In his experience, as the result of careful testing under independent inspection, coking-stokers were more applicable to lightly fired boilers, and by means of them better economy was secured than by hand-firing. But shovel-stokers could be used for heavy firing. He found that, provided there was no considerable raking of the

[1] The correct weight of fuel consumed per square foot of grate worked out to 47 lbs. per hour, and not 50 lbs. as stated. The machine-stoker consumed 70 lbs. per square foot of grate per hour—the grate however being much smaller. The guaranteed work—30 per cent.—was accomplished with an increased consumption of only 15 per cent. in the boiler.

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fires, the greater the consumption per hour, the greater the economy. On the contrary, in working by hand-firing it had been found that light firing produced the most economical results. A machine-stoker of the shovel type, from the regularity of its action, produced a more intense heat when urged up to its full power. As an illustration of this, he would mention that he was now conducting a week's test at an important Lancashire paper-works where seven boilers were ordinarily used. He had at first tried six, but that morning he had reduced the number to five, having found that the machine-stoker was making too much steam, and even now there was more than was necessary. The reason was partly that stated by the Author, and partly also because the regular and intense fire being always clear from smoke, produced a greater heat in the boiler tubes, and the water took it up more rapidly. Again, when the flue gases reached the economizer they did not carry so much smoke with them, and the pipes did not get clogged up, so that a greater heat was attained there, as well as round the boiler. At the paper-works spoken of, the additional result obtained in the economizer was not equal to that attained in the boiler itself. The water leaving the economizer was only 30° hotter with machine-firing than during the previous hand-firing test when seven boilers were being used; so that there was an increase in the work of the economizer of 14 per cent., whereas each boiler was doing 40 per cent. more. The flue-gases entered the economizer at an average temperature of 750°, and left it at 450°, losing 300° in raising the water from 210° to 240°. Recurring to the low evaporation of 7 or 8 lbs. per lb. of fuel, the fact must be taken into consideration that most firms endeavoured to use cheap coal. Frequently 2*s.* to 4*s.* per ton was saved in country places where, as the boilers were heavily fired, the mill-owners were compelled to use good coal for hand-firing. At the Palmer mills mentioned by Mr. Eskrigge, from 8 to 12 tons of coal was saved per week out of 96 tons, in addition to obtaining a considerable increase of power. It might be said that the machine-stoking had decreased the number of boilers used. That was so; but the three boilers were doing more work than the four formerly did by hand. Frequently with machine-firing 30 to 40 per cent. extra work was done on a given range of boilers, while the labour to the men was lessened. With regard to gas-firing, he had made an exhaustive series of tests at the Bilston Steel Works with Mr. Lithgoe, and the conclusion come to was, that no gas-firing could compete with the direct combustion of coal in the boiler, because it was not economical to carry on two

Mr. Bennis.

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Mr. Bennis. processes when the same result could be obtained by one. He formerly shared the popular belief among engineers, that when carbonic acid gas was passed over coke fires, carbonic oxide was largely produced. His opinion now was that this was an error, as in no case had he been able to detect carbonic oxide in considerable percentage in flue-gases from boilers, and Mr. Fletcher had shown in his numerous experiments that carbonic oxide could rarely be got out of boiler-chimneys. They might, of course, find a trace; but the gas was so inflammable that if there was any air present it would burn. Under these circumstances he was unable to account for the fact, having made a good many experiments with coke-firing, that they could not get the same evaporative duty per lb. of coal, nor the same work out of a boiler by coke-firing, even with a steam-blast. Of course in steel-works where they had short chimneys and great pressure, the carbonic oxide would come out of the top of the chimney and burn there, but he was speaking of boiler-flues. Mr. Fletcher, who had made a great many more experiments than he had, said that only where there was dense black smoke did any carbonic oxide escape from chimneys.

Mr. Sugden. Mr. THOMAS SUGDEN said one thing that appeared to him peculiar in the two systems of stoking was the length of the fire-bar, which was shortest in that machine in which apparently it ought to be longest. The coking-stoker, where part of the surface of the grate was taken up by the coking, had a very short bar, while the sprinkler-stoker, where the whole of the fire-bar was available for making steam, had a much longer one. He should like to know the reason of this. With short fire-bars the heat was too much localised, and would have rather a detrimental effect upon the boiler from being confined to such a limited space. With respect to the windage and the admission of air to support combustion, the Author stated that the moving-bar kept the spaces open, and in consequence a much greater velocity of air escaped through. He imagined that this greater velocity of air was due rather to the grate-surface, which, in all mechanical stokers, was much smaller than in an ordinary furnace. In the ordinary Lancashire boilers the grate-surface would be 6 or 7 feet long at the least. In Bennis's stoker the bars were 5 feet, and in the Vicars about 3 feet 6 inches long, so that in burning the same amount of fuel the necessary quantity of air would have to pass through a smaller area, and consequently the velocity must be greater. He preferred this explanation to that given by the Author, namely, that the bars were always clean. In the Vicars's stoker there

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was a steam-jet to cool the end of the fire-bars, and in the other stoker the steam-jet was used to keep them clean and cool; but he should think that they required an account of the smaller grate surface that the draught should be assisted. Most people, in putting up mechanical stokers, would find that unless they had a very good draught they would not work so well, because with a limited grate-surface a stronger current of air was needed; so that possibly they might not get the same result unless they employed some kind of forced draught. In his experience one of the great difficulties about mechanical stoking was that of constructing the machinery, and also of keeping it in order. Making fire-bars 5 or 6 feet long was a serious matter, and in most instances they did not last a great while—sometimes not more than a few weeks. In addition to this there was a natural prejudice on the part of firemen against mechanical stoking, because they thought it would do away with skilled labour and make their positions worse. It was necessary that people who put on mechanical stokers should consider that when men were determined that a machine should not work it was very rarely indeed that it was found to go satisfactorily. He had with him the results of some experiments which he had made with the coking-stoker, extending over a period, in one instance, of seventy-four days, and in another instance of fourteen days. By hand-firing during fourteen days, 159 tons of coal at 15*s.* 3*d.* a ton. were burnt. That quantity of coal forced 2,375,176 gallons of water into the main against the constantly accumulated pressure of 720 lbs. per square inch. When mechanical stokers were fixed for the same boilers, the result was that 492 tons of coal burnt, at 11*s.* 3*d.* a ton, forced 10,146,583 gallons of water into the main under the same conditions. In this case mechanical stoking just saved the difference in the price of the coal, or about 25 per cent. The evaporative tests in both instances were nearly the same. Mr. Sugden.

Mr. W. H. Preece wished to emphasise one point raised by Professor Kennedy, because it introduced a problem that was exercising the minds of electrical engineers, and compelling them to call in the aid of the mechanical engineers, and especially of those who advocated mechanical stoking. The variation of load during a day of twenty-four hours was a very serious item, and he would put it before them in the shape of a diagram. The horizontal line, *Fig. 2*, represented the day, starting from midnight, and the load of the apparatus in the central station, that was to say, the HP. converted into the electrical energy supplied to the district, was measured upon the Mr. Preece.

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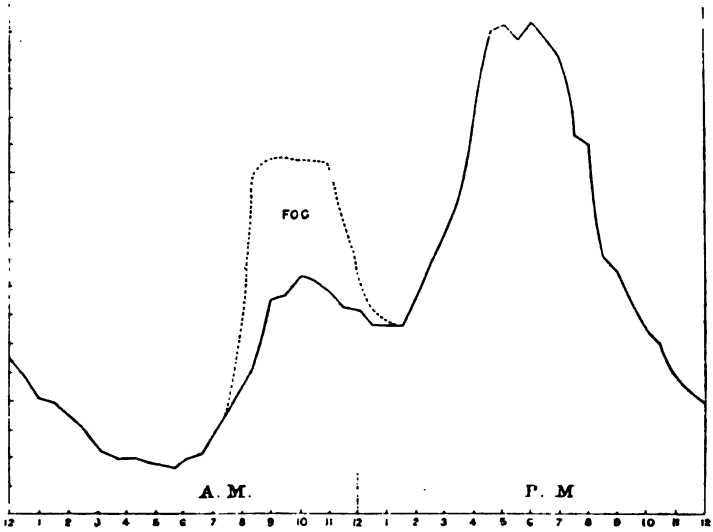
Mr. Preece. vertical lines, which might represent any amount of power they chose, say 1,000 HP. At twelve o'clock at night there were still a few dissipated gentlemen found out of their beds, and a certain amount of light was used, which dwindled down to something very small at four o'clock in the morning. At that hour there was always somebody wanting light, and busy men like engineers were commencing to rise. At times on dull mornings they required light at the breakfast table, and the load mounted. Then breakfast being over, having read the newspaper and gone to business, the load fell again, and at twelve o'clock it reached

Fig. 2.



a minimum. At that time of the year between three and four o'clock in the afternoon there commenced a very sudden rise—shops, offices, places where business was transacted required light; and not satisfied with light in their business places, they required light when they went home and dressed for dinner, at which time between seven and eight o'clock at night there was the maximum power required at the station. When they had gone to the theatres the load descended at a rapid rate until it reached, at the end of the diagram, about the same value which it had at the commencement, twenty-four hours previously. This was an illustration of the way in which the load of a central electric-lighting station might vary. From four o'clock until six

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there was a sudden rise from about 50 or perhaps 100 HP. up to 1,000 HP. Of course, at the present moment, he was dealing with electric lighting, because the public generally were not yet educated to the use of small motors. When they did become so educated the diagram would be rather modified. Electrical engineers had watched with a good deal of interest these mechanical stokers. In the new Post Office, when they introduced pneumatic tubes the boilers were fitted with mechanical stokers, and they found the variation of load was very much of the same character. Naturally when the business man got to his office at about eleven o'clock he sent messages away with great rapidity up to twelve o'clock, and if he were to draw a curve indicating the variation of the telegraphic service, the maximum point would come at twelve o'clock midday, instead of late in the evening. It was quite impossible to get that sudden rise of work by means of the mechanical stokers, and they were obliged to remove them. He had had a good deal to do with electric-lighting stations, but there was only one central station that he knew of in this country where mechanical stoking had been introduced, viz., at Newcastle,[1] and they were watching its performance with a good deal of interest. It had only been running a few months, so that nobody could tell at present what the result would be. He would call the special attention of those who were dealing with mechanical stoking to the question of the great rise between the hours of four and six o'clock shown on that diagram. The effect of a fog in the morning would be to cause a sudden increase of the load in the morning, as in the case he had mentioned of the pneumatic tube. Mr. Preece.

Mr. J. F. SPENCER, in reply, said the great care with which Professor Kennedy always made his experiments warranted the supposition that a very efficient set of men were employed as stokers. One of the chief reasons for bringing forward the Paper was that good stokers were very few. The bulk of the work carried on in the country was done by men who were seldom faithful to their duty, and it was undesirable to depend upon a system where the majority of those who had to carry it out were so inefficient. The necessity of mechanical stoking arose mainly from the circumstance that it was so hard to get what was called careful hand-firing. The difficulty at sea at present was to obtain efficient firemen, and if the system of mechanical Mr. Spencer.

[1] He had afterwards learnt that they were used in the central stations in Liverpool.

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Mr. Spencer. stoking in a modified and perhaps better form could be applied to the Navy and mercantile marine, the advantage would be simply immense.

It was noticeable that every defence of hand-stoking omitted reference to the importance of the "uniformity" in the production of heat, which was the special characteristic of machine action as contrasted with hand-work. As a striking illustration of the value of economical arrangements that could not be materially altered by the man in charge, reference might be made to the greatly increased average economy of steam-power which resulted from having an unalterable expansion, as in the differential cylinders of compound or triple-expansion engines, in place of a cut-off gear regulated by ignorant and often incapable men. With regard to Professor Kennedy's remarks as to the economy of labour, in Perth, it amounted to one-third; and the steam-user would not consider that "very small"; the circumstances, however, in that case, were not specially favourable. With reference to the anemometer tests in the ash-pit it was not implied that the supply of air was increased in the ratio of the figures given, but that the draught was made much greater by the adoption of machine-stoking, giving, in fact, an increase in evaporative duty of upwards of 40 per cent., with inferior coal. The following table of actual tests made by Mr. Bennis formed the basis of the Author's estimate of the weight of steam used for twelve boilers:—

OUTFLOW OF STEAM INTO THE ATMOSPHERE (1882).

Boiler Pressure.	Supply-Pipe.	Distance from Boiler.	Exit Holes.	Lbs. Steam Used.	Velocity. Feet per Second.
Lbs.	Inch.	Feet.	Inch.		
82	$\frac{1}{2}$	6	16 of $\frac{1}{32}$	342	1,300
82	$\frac{1}{2}$	6	16 „ $\frac{1}{16}$	916	1,200
82	$\frac{1}{4}$	6	16 „ $\frac{1}{32}$	255	950
81	$\frac{1}{4}$	6	16 „ $\frac{1}{16}$	722	850
82	$\frac{1}{2}$	3	1 „ $\frac{1}{2}$	5,370	1,150

It was a matter of regret that so little reference was made in the discussion to coking-stokers, and it might be fairly assumed that whether the coking or the sprinkler type of machine should be adopted would depend to a great extent on the special circumstances of each case. If the attention of engineers and

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steam-users could be directed to the importance of substituting these machines for human stokers the results might prove as important in economizing the production of steam, and in purifying the atmosphere of the manufacturing towns, as those derived from the use of increased pressure and engines of improved construction. Mr. Spencer.

Correspondence.

Mr. F. COLYER noticed that the Author stated that the Juckes' furnace "was deficient in power and not economical," and that "the attempt to adapt this stoker to Lancashire boilers was not successful." Speaking from personal experience he might state that he had used these furnaces largely for nearly thirty years. They had been most successfully applied to Cornish and Lancashire boilers, and also on a large scale to brewery coppers; in the case of boilers, they had been employed inside the tubes as well as under the shell. For coppers they had been used by him in sizes of from 15 to 54 square feet, and in boilers from 15 to 40 square feet. The saving effected in the cost of coal was from 20 to 25 per cent., allowing for the wear and tear of the furnaces. In experiments and tests made by him some years ago, using two 35 nominal HP. Lancashire boilers, 1 lb. of common slack coal evaporated 10½ lbs. of water. These experiments were made at a large sugar-house, and were spread over a period of one week; the coal bill at this place at the end of the year, taking into account the number of hours the boilers were worked, showed a saving of at least 25 per cent. He also carried out some tests at one of the largest breweries in Burton-on-Trent, where these furnaces were applied under brewing-coppers, and found that with the commonest slack and dust from a Midland Colliery, the saving in cost of coal was 30 per cent. As to the evaporative power in this case, repeated tests were made with two coppers worked side by side, into each of which sixty barrels of water were put, one of them being heated by an ordinary hand-fired furnace with large coal, and the other by a Juckes' furnace with common slack. The water in the copper heated by the Juckes' furnace was boiled in two-thirds of the time required in the case of the one heated by an ordinary fire. He could quote many similar instances where experiments had fully established Mr. Colyer.

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Mr. Colyer. the large economy of this type of furnace. One of the largest breweries in London had used Juckes' furnaces for about forty years, and they still had twenty-two large ones at work and found them the most economical furnace for the purpose. Nearly all the large brewers, both in London and Burton, employed them, and during a long experience he had never known them to fail. He had many times successfully applied these furnaces inside the tubes of Cornish and Lancashire boilers, the tubes being from 2 feet 6 inches to 3 feet in diameter, and found that the economy was as great as when they were placed under the shells of other boilers of like type. He was aware that there were failures some years ago in the cotton districts, where the furnaces were constructed by inexperienced people and were badly made, but in this case the manufacturer should take the blame. The fact that for forty years they had been and were still largely used was the best answer to the Author's statement. There were several other furnaces not named, that had been extensively used for the prevention of smoke, such as Copeland's, where the coal was introduced under the fire. The objection to this method was not any want of economy, but because only those kinds of coal could be used that would cake together. The Paper might have been entitled "A description of Vicars' and Bennis' Machine-stokers," but Mr. Colyer considered that there were others of the same type, equally good, which should have been described if prominence was to be given to any particular class. There was nothing novel in either of the furnaces described. Jets of steam were used under the fire-bars upwards of twenty years ago and were still employed by many people. He fully endorsed Professor Kennedy's statement that the expenditure of steam in the jets described was more than many people supposed; it probably cost more than any saving effected by the increased draught or the preservation of the bars. Pans of water placed under furnace bars would prevent them from burning out rapidly, and would also help the draught when it was sluggish, and this plan involved no expenditure of steam. The evaporation per lb. of coal by Vicars' furnace, viz., 8·98 lbs. water, was far behind that effected by Juckes' furnace, which would evaporate from 10 to 11 lbs. of water per 1 lb. of fuel of the same quality. He had lately seen near Glasgow Juckes' furnaces working under water-tube and other large boilers with great economy, the heating power and easy way in which steam could be kept up being all that could be desired. If they could be used with advantage where the coal was so poor and so cheap it was surprising that many large firms did not apply them.

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He might state that he had no interest in either Juckes' or any other furnace. He had refrained from entering into any particulars of other good furnaces for the prevention of smoke because they were not named in the Paper. It was to be regretted the Author did not treat his subject more fully and generally instead of confining himself practically to the description of two out of many machines of this class. With reference to the remarks of Professor Kennedy and Mr. Preece, there was no difficulty in working any of the good mechanically-fired furnaces, where the demands for steam were not regular, as the speed could be adjusted to suit and the motion of the bars stopped if necessary. There was no doubt that furnaces of this class supplied a more regular amount of steam than hand-fired furnaces, and that there was a great advantage in working with a thick and even fire, and in not having to open the fire doors and let in cold air to the top of the furnace where it was not required, and where much damage was done to the plates of the boiler. The most severe test of this kind was in the case of a brewery copper, where the fire had to be entirely drawn immediately the wort was sufficiently boiled, and then quickly returned to the furnace in order to boil the next quantity. In the case he had referred to one-third of the time was saved by the use of Juckes' machine. He had also had other cases, where steam wharf-cranes were employed, and where the demand was intermittent. Machine-furnaces had been found in practice to be the best, and by far the most economical and efficient in every case where they had been intelligently applied. Mr. Colyer

Mr. G. D. Dennis remarked that he had had long experience in the management of hand-fired boilers, and one of the largest private electric-lighting stations was now under his superintendence, where there were four double-flued boilers 30 feet by 7 feet 6 inches. Two of these had been fitted, by his advice, with Vicars' mechanical coking-stokers. So far they had given every satisfaction, and as much steam could be obtained from these two boilers, with small-coal costing 10*s.* 6*d.* per ton, as from the other two using best Nottinghamshire steam-coal at 18*s.* 6*d.* per ton and firing by hand. These machine-stokers would meet a sudden call quite as quickly as hand-fired boilers, and they only required to be tried under such conditions as existed at electric-lighting stations to be generally adopted. They had given no trouble, and the chimney was always clean. More coal could be burnt with them than by hand-firing, and with this advantage, that Mr. Dennis.

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Mr. Dennis. the mechanical stokers always put the coal in the right place, viz., on the dead-plate end of the furnace, thus causing all the products of the early combustion of the fuel to pass over the incandescent mass. Arrangements were being made to fit the other two boilers with machine-stokers of the same make.

Dr. Proell. Dr. R. PROELL was convinced that apparatus of this kind was capable of giving good results with respect to economy of steam and smokeless firing, and he found no difficulty in accepting the Author's figures with regard to those points. But it was doubtful whether it would also be possible to keep the machine constantly in good working order. The separate parts would suffer a good deal from the strong heat radiated by the furnace and would soon warp to such an extent as to become useless. Mechanical stokers would not be very largely taken up in Germany. In that country the greatest stress was laid on the thorough training of the stokers in special schools for firemen. In this way the people learnt what were the conditions of economical and smokeless firing, and the boiler-makers also on their side were urged to build furnaces in which these conditions could be realized. Systematic practical experiments with various kinds of boilers had shown that it was actually possible to obtain an economical and almost smokeless combustion with hand-firing. That was the conclusion to which he had been led by his own experience. If in England the system adopted with respect to the teaching of the firemen was different, then there might be scope for mechanical stokers. But besides these things the quality of the coal and the nature of the demand for steam had to be taken into account. If the former coked very much and the latter was variable, then the machines would not behave so well as they were otherwise capable of doing.

Mr. Reynolds. Mr. EDWARD REYNOLDS hoped that the question of the application of machine-stoking to marine purposes would be raised. The chief difficulty appeared to be that a steam-ship did not average a level floor, and that in consequence, one side of the bars became bare when machine-stokers were used; considering, however, that circular furnaces were almost universal, and that such variations of weather as would make a permanent change in the average list of the ship were not sudden, it would appear to be perfectly practicable to make an automatic device whereby the position of the bar-frames, &c., in the circular flue might be adjusted to suit the average list of the ship on its course, and this having been provided for, the

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makers of machine-stokers would find an enormous field open to them. Mr. Reynolds.

Mr. SPENCER, in reply to the correspondence, observed that Mr. Colyer's reference to brewers' coppers, to which the Juckes furnace had been applied, was quite outside the scope of the Paper, which was limited to steam engineering, and Mr. Spencer did not consider it necessary to discuss the success of such application of the system. In support of his statements about the Juckes furnace, so much objected to by Mr. Colyer, he would give the following reasons:— Mr. Spencer.

1. One firm alone fitted upwards of one thousand Juckes furnaces, of which only about one hundred continued in use after three years, and at the present time it was doubtful if one remained.

2. Eight or ten firms made Juckes furnaces for steam-boilers, and yet discontinued the manufacture. It was hardly to be supposed that they all made the grates faulty.

3. The Author, in visiting the Midland districts in 1882 and 1889 for the purpose of seeing various machine-stokers in operation, did not meet with or hear of a single Lancashire or Cornish boiler working with a Juckes grate.

4. Mr. Colyer did not give the name of any steam-user now working a Juckes grate in a Lancashire or Cornish boiler.

5. The estimated number of Juckes and similar grates now working, as stated in the Paper, which was believed to be in excess of the truth, proved that the experience of fifty years had not been in favour of their general adoption.

6. In 1886 some competitive trials between a Juckes and a Bennis furnace were made at the Bolton Iron and Steel Works with results unfavourable to the former, in which the fire-grates were under the boilers.

The chain-grate was a step in the right direction, but it was practically out of the market now. Mr. Colyer's objection to the omission of particulars of other machine-stokers was hardly reasonable. The title of the Paper was "Machine-Stoking" and not "Machine-Stokers," and in order to illustrate the two types it was but just to select those most generally adopted.

In answer to Dr. R. Proell, no doubt the question of wear and tear was most important in machine-stoking, and the arrangement that was least complicated had the greatest chance of permanent success. The Author was much impressed with the simplicity and efficiency of a coking-stoker at Oldham, shown to him by

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Mr. Spencer. Mr. Herbert Fletcher, of Bolton, an ardent advocate of smokeless furnaces. Dr. Proell's belief in an educated human smokeless and economical stoker was a most delusive one. With regard to Mr. Edward Reynolds' suggestion, the automatic device for obviating difficulties due to the list or roll of a steamer had been fully proved to be unnecessary with machine stoking at sea.

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3 February, 1891.

SIR JOHN COODE, K.C.M.G., President,
in the Chair.

It was announced that the following Associate Members had been transferred to the class of

Members.

WILLIAM BARRINGTON, Jun.
SIDNEY HOWARD FARRAR.
SINGLETON GOODWIN.
JOHN WYKEHAM JACOMB HOOD.
CHARLES LOXTON JACKSON.
JOHN ARTHUR DAYRELL LLOYD.
PERCY RICKARD.
EDWARD BLAKEWAY SMITH
ROBERT HENRY FREDERICK STUART.

and that the following Candidates had been admitted as

Students.

CHARLES SPENCE ANGUS.
JOHN CALDER, Wh. Sc.
HAROLD CORDEROY, B.Sc.
ERNEST GRAY COUTTS.
WILLIAM HARVEY EBBS.
GEORGE ADAM HART.
GODFREY WILSON MOORE.
HENRY HAWKINS MYBURGH.

The candidates balloted for and duly elected were as

Members.

FREDRICK ATTOCK, Assoc. Inst. C.E.
ALFRED PANCOAST BOLLER, M.A.
ALEXANDER BREBNER.
MARSHAL CRESSWELL.
ROBERT CRICHTON.
GEORGE ROBERT MOYLE FIELD.
WILLIAM SUTCLIFFE MARSH.
SAMUEL REA.
JAMES DIX SCHUYLER.
WILLIAM BELLHOUSE SCOTT.
WILLIAM POWELL SHINN.
MATTHEW STIRLING.
FREDERICK WILLIAM WALKER.

Associate Members.

JAMES ARMER.
CLAUDE WILLIAM ATKINSON, A.K.C., Stud. Inst. C.E.
HENRY CUTHBERT BARNARD, Stud. Inst. C.E.
ROBERT BARNES.
CHARLES WILLIAM JOHN BEARBLOCK, Eng. R.N., Stud. Inst. C.E.
GEORGE ARTHUR BECKS, Stud. Inst. C.E.

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Associate Members—continued.

WILLIAM CAMERON BORROWMAN, Wh. Sc.
ARTHUR CROMPTON BROWN.
BENJAMIN JOHN ELDER BRUCE.
GEORGE CUNNINGHAM BUCHANAN, Stud. Inst. C.E.
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DAVID COE.
PERCY BARBY GUSTAV OTTO CROWE.
AUGUSTINE CAMPBELL DAVISON, Stud. Inst. C.E.
SYDNEY THORNTON DOBSON.
EDMUND ROBERT DYMOND, Stud. Inst. C.E.
FREDERICK CHARLES FAIRHOLME, A.K.C., Stud. Inst. C.E.
CHASEMORE PHILIP GATES, Stud. Inst. C.E.
CHARLES ERNEST VERE GOUMENT.
PHILIP HAMMOND.
HERBERT WILLIAM HARPER.
ROBERT JOHN HARRISON.
WILLIAM HARSTON.
FRANK HOWARTH, Stud. Inst. C.E.
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CHARLES FREWEN JENKIN, B.A., Stud. Inst. C.E.
LUCIEN ALPHONSE LEGROS, Stud. Inst. C.E.
SYDNEY LE GROS, Stud. Inst. C.E.
JOHN GEORGE LIVERSIDGE, Eng. R.N.
SAMUEL ERNEST LUCAS.
WILLIAM THEODORE LUCY, Stud. Inst. C.E.
GEORGE EDWIN JAMES MCMURTRIE.
ERNEST ALFRED WILLIAM PHILLIPS.
JOHN PIDGEON.
FRANCIS JOSEPH PIGOTT, Stud. Inst. C.E.
WILLIAM EDWARD PRICE.
JAMES FRANCIS READE.
JOHN EDWIN ROGERSON, B.A., Stud. Inst. C.E.
JOHN THOMAS HORNSBY SAMPLE, Stud. Inst. C.E.
EVELYN FRANCIS SANDERS, B.E.
RICHARD WILLIAM SMITH.
WILLIAM SMITH.
CHARLES ARTHUR STRUTT.
CHARLES ROBERT TREWHELLA, Stud. Inst. C.E.
WALTER FRANCIS AINSLIE WADHAM, M.A., Stud. Inst. C.E.
CLAUD ROBERT WATSON.
WALTER WILSON, Stud. Inst. C.E.

As an Associate.

ERNEST MONCREIFF PAUL, Lieut. R.E.

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(*Paper No. 2497.*)

"Electric Mining-Machinery, with Special Reference to the Application of Electricity to Coal-Cutting, Pumping, and Rock-Drilling."

By LLEWELYN B. ATKINSON, A.K.C., and CLAUDE W. ATKINSON, A.K.C., Assoc. MM. Inst. C.E.

THE employment of electricity in mines for pumping, hauling and coal-cutting, is a subject which has already received some attention in Papers read at the meetings of the more strictly mining Institutions. The Authors have been, during the last four years, constantly connected with the applications of electricity to mining, and have spent a considerable amount of time underground, both in making experiments, and in teaching those who would have to take charge of the Electrical Machinery. They propose in the present Paper to show in what way the conditions of mining work differ from those of other industries, and how the problem has been dealt with, illustrating the subject by describing some of the machinery now in actual use.

The principal uses to which electrical power is likely to be put in coal- and metalliferous mines, and in quarries, are the driving of pumps, of hauling and underground winding-machines, of coal-cutting machines, of drilling-machines, both rotary and percussive, and in certain cases of fans for subsidiary ventilating purposes. It will be unnecessary here to dwell at any great length on the question of the relative merits of different methods of transmitting power in mines, practical experience having shown that compressed-air is almost the only rival to electricity, although in particular instances other systems are still in use for certain purposes. Compressed-air has one advantage, on which much stress has been laid, namely, that the exhaust product is in itself a valuable assistance to ventilation; but from circumstances that will presently be described, it would appear that the method of ventilating a mine by first compressing air, transmitting it under pressure, and then expanding it, is the most costly that can be devised. If power must be spent in ventilation, the best way to do it is to deliver a given volume of air, with the proper difference of pressure between the intake and the up-

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cast. In using compressed air, in order to keep the machinery as small as possible, and at the same time to limit the expense of the piping, it is necessary to work at as high a pressure as is feasible. On the other hand, increase of pressure, which in a steam engine conduces to greater economy and efficiency, is, in the case of compressed air, the one item which reduces the efficiency.

The following Table[1] gives the result of experiments made some years ago by Messrs. J. Fowler and Co., of Leeds, who have had considerable experience with air-compressors.

GROSS EFFICIENCY OF COMPRESSED AIR IN THE TRANSMISSION OF POWER.

Air-pressure. Lbs.	Efficiency $= \frac{\text{Brake HP. of Motor.}}{\text{I. HP. of Compressing Engine.}}$ Per Cent.
40·0	25·8
34·0	27·1
28·5	28·5
24·0	34·9
19·0	45·8

The above results are borne out by the experiments made more recently by Professor A. B. W. Kennedy, F.R.S., M. Inst. C.E., on the transmission of power by compressed air in Paris on the system introduced by Mr. Popp.[2] These experiments show that the brake HP. of the motor (10 HP.) is 31 per cent. of that of the engine driving the air-compressor if the air is not heated before it is used in the motor. If the air is heated and expanded before passing into the motor this efficiency is increased to 45 per cent. In mining work it is generally difficult to do this, and consequently engineers are content if they can obtain the lower result.

The great advantage of heating and expanding the air before passing it into the cylinder was so far realized by Mr. Frederick Hurd, in 1872, that he devised an arrangement for placing a heating apparatus inside the valve-chest, in which the oxygen for the combustion of the fuel (a mixture of coke and scrap-iron) was supplied by the air working the motor. By this means the possibility of exploding fire-damp is completely overcome, and the formation of ice is avoided.

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[1] "On Compressed-Air Machinery for Underground Haulage." By Mr. William Daniel. Proceedings of the Institution of Mechanical Engineers, 1874, p. 210.

[2] See Report of the British Association, 1890.

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In practice 40 lbs. or 50 lbs. is about the pressure now adopted for working compressed-air machinery, although in the case of rock-drills, where lightness, portability of the machines, and smallness of the connecting hose, are of greater importance than efficiency, 70 to 90 lbs. per square inch is frequently used. The final result, however, of experiments at these pressures, agrees with that already given, namely, that it is impossible with compressed-air to transmit to the distant motor more than from 20 to 30 per cent. of the power expended in the engines, and probably, taking due account of the friction and loss in the piping, which, however, is not often excessive, the average efficiency of compressed-air as applied to mining work would be below 20 per cent. In the case of electrical transmission of energy, except when distributed into very small units, there is little difficulty in obtaining 50 per cent. of the power expended in the engine, and there are cases in which no less than 75 per cent. is transmitted without any extraordinary precautions being adopted.

These figures are frequently contradicted by the advocates of compressed-air, but after the precise particulars which have been published of experiments with electricity, and in view of the scanty information obtainable as to actual trials of compressed-air, the onus lies with its advocates to show that the results which can be obtained in regular working by this method exceed those already given. In addition to this lower efficiency, which means not only a greater expenditure of coal but also a large increase in the dimensions of the engine, and consequently in the price of the generating-plant, there is the cost of laying and maintaining the connecting-pipes. To make the matter clearer, a simple case has been chosen, and Table II, Appendix, prepared, showing the comparative economy of these two methods of transmitting power.

It must be borne in mind that the size of the cable plays a large part in determining the efficiency of the electric transmission of power. In the case of steam, compressed-air or hydraulic transmission, the losses in the pipes are frequently neglected, as they are usually small. This cannot be done with electrical plant, first, because the cost of the copper conductors forms a considerable item in the whole, and it is therefore desirable to have them as small as possible under the particular circumstances of each case, and secondly, because, unless the cables are proportioned to the power to be transmitted, they may become heated and damaged by the current passing through them.

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In dealing with dip-draining pumps the Authors have given a Table showing the loss of power in the cable in two particular cases, with small machines, but they think that a similar Table dealing with large machinery and varying sizes of cable may be of interest. They have, therefore, in Table I, Appendix, given the losses in each part of an electrical pumping system, first, with a pump delivering 350 gallons per minute against a vertical lift of 900 feet and a pipe line 1,800 yards long of 6-inch pipes, and secondly, with a similar pump delivering 200 gallons per minute to a height of 480 feet through the same pipe line. It will be seen that an efficiency of 67 per cent. can be readily obtained even when transmitting nearly 100 HP. to a distance of more than 2 miles, and without any attempt being made to get specially good results, the whole plant being such as can be worked by unskilled men.

The results given, are, it is true, now recognized to a large extent as being, in the abstract, correct statements of the facts; but in the minds of the owners and managers of collieries and mines, there still exists a doubt as to when they are justified in adopting the use of electricity. One of the most important points which has been raised in this connection, and which was brought very strongly to the front in the discussion on a Paper by Mr. Blake Walker,[1] read at a meeting of the Midland Institute of Mining Engineers, is the question "of the safety, or otherwise, of an electric motor in a coal-mine, in view of the fact of the explosive nature of the gases existing in some parts of most mines."

The problem resolves itself into two parts—First: Will a motor, working under ordinary and satisfactory conditions, be likely to cause an explosion, assuming that it is placed in the positions where motive power is usually required in mines? Secondly: Is it possible under what may be termed extraordinary, but perfectly realizable conditions, to produce an explosion under similar circumstances?

A variety of opinions on the subject have been given, and some experiments have been tried bearing upon it, and the Authors consider that the following may be taken to be a correct summary of the results obtained.

In the case of an ordinary motor working up to, say, 500 volts, having the brushes properly adjusted upon the commutator,

[1] Transactions of the Midland Institute of Mining Engineers, vol. xi. p. 317. "Electricity as a Motive Power," with special reference to its application to mine-locomotives, December 1889.

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no sparking can be perceived, but if from wear of the contacts during long runs, or variation in the load, slight sparking should occur, it is produced in contact with large masses of a highly conducting metal (copper), with the result, that the rise of temperature is not sufficient to fire explosive mixtures of coal-gas and air, or ordinary marsh-gas and air. The temperatures required to explode these gases at ordinary pressures may be taken to be, for a mixture of 1 volume of coal-gas, with 5 volumes of air, or for a mixture of 1 volume of marsh-gas with 9·4 volumes of air, from 900° to 1,100° Centigrade.

Copper combines with oxygen in air so as to produce oxide of copper at about 700° Centigrade, and as under normal conditions the formation of this oxide is not observed, either on the collector or on the point of the brush, this fact may be taken as further evidence that the temperature there existing is not sufficient to fire an inflammable mixture of gases. It may be said then, that under normal conditions, an electric motor is not a dangerous machine to use even in an atmosphere charged with considerable quantities of explosive gases; but having shown this, it may be admitted that supposing a brush, for example, is worn so far that it ceases to be in contact with the commutator, or supposing it to become seriously displaced from its proper position, an amount of sparking may ensue, which will cause a temperature sufficiently high to oxidize the copper of the brushes, and farther, to ignite inflammable mixtures. The question then arises, how is it possible to obviate the danger which may arise from this cause?

The Authors, having devoted considerable attention to this matter, have adopted the methods illustrated in Figs. 1, 2, 3, 8, &c., as a means of excluding from the armature the atmosphere in which the machine is working. It should be taken as an axiom that the machine will not normally be placed to work in an explosive mixture; but that what has to be guarded against is, in the case of a motor which perhaps is not attended to for some hours at a stretch, the accumulation of such gases in its neighbourhood during this time. Moreover, where a motor is in use at the coal-face or in a heading, means should be adopted to allow the machine to be stopped if, in the working of the coal, or from the fall of a roof or other reason, an inrush of fire-damp should take place, before this explosive gas has had time to come in contact with the commutator and brushes.

To effect this purpose, the Authors have adopted the practice of enclosing, either the whole armature together with the commutator and brushes, or when this is inconvenient, the commutator

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and brushes only, in a casing which is air-tight, or practically so. It has been objected to this plan, that although it may be feasible in the case of small motors, it is impracticable with machines of any size, owing to the diminished ventilation of the armature and commutator. The Authors have, however, adopted the method with success for a motor which has developed up to between 40 and 45 HP., and with no greater difficulty than in the case of one as small as 1 HP. In the winding of field-magnets, it is now recognized that any desired temperature of working may be obtained by allowing well-defined amounts of external cooling-surface for the dissipation of the heat developed. This proportion, for a final temperature of 70° F. above the atmosphere, may be taken as 2·3 square inches per watt to be dissipated.

The armatures of ordinary dynamos and motors are constructed to revolve in contact with the air, and the continual cooling thus obtained allows the surface for each watt to be dissipated for the same rise of temperature, to be diminished to about 0·7 square inch. In the case of the Authors' mining motors, it is only necessary to revert to the basis adopted for the field-magnets, that is to say, to allow a cooling-surface on the exterior of the armature-casing of the proportions which would be adopted for a stationary magnet-coil, in order to obtain the same result as to temperature. The armature revolving inside quickly brings the contained air to the same temperature, and this, being in rapid movement, conveys the heat to the external casing, from the surface of which it is dissipated by radiation and convection. It is true that to obtain a proper proportion between the cooling-surface and the heat generated, it has been necessary to be careful as to the magnetic and electrical design of the armature, but with these precautions, the Authors have found that the temperature of the armature of these enclosed motors at the end of a long run does not exceed that of the field-magnets.

Having thus disposed of the objection which has been raised by electrical engineers to this method, it remains to consider the question from the point of view of the mining engineer. The argument of the mining engineer is that if these casings should become filled with an explosive mixture and ignited, the result would be as disastrous as if they did not exist. The answer to this objection is as follows:—Seeing that under certain sections of the Coal Mines Regulation Act it is not allowable to work where the proportion of explosive gas exceeds about 1 in 30, it is not likely that any electric motor will be

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placed in such a position as to be run continuously in an explosive atmosphere for a longer period, at the outside, than two or three hours. The casings with which they are provided are tightly fitted at all the joints, many of them being packed with rubber, and it is not likely that an inflammable mixture could penetrate to a dangerous degree within that time. Should there, however, be any leakage into the covers, as soon as the proportion of marsh-gas in the air reaches 3 or 4 per cent., combustion will take place quietly, producing carbonic-acid gas, which will tend to prevent explosion.

If, however, it is required to work for long periods in such an atmosphere, the Authors would provide means for the introduction into the armature of an inexplosive mixture. The simplest method of producing this result would be to attach to the motor a steel cylinder containing carbon dioxide under pressure, and to connect this with the armature-casing by a pipe which should allow a slow but constant stream of this gas to reach the interior of the casing. The efficacy of this method may be judged when it is pointed out that the presence of 14 per cent. of carbonic acid gas in the most explosive mixtures of fire-damp renders them absolutely uninflammable. The Authors consider that this method of protecting the armature and commutator, and preventing the ingress of an explosive mixture, is generally more satisfactory than that of enclosing the commutator and brushes only as mentioned before. Conditions may, however, arise which render this latter method desirable. In that case the point to be aimed at is to produce a cover which shall give a similar protection to that afforded by a safety-lamp, and allow the ingress of the explosive atmosphere, but prevent the egress of flame. In order to do this it is necessary that the volume of the enclosed gases should be small, and that the passages through which the flame can escape should be of sufficient length, and the metal surfaces close enough together to cool it below the point of combustion. If the commutator were enclosed by a cylindrical case or otherwise, so that the volume of gas was small to begin with, yet as it wore away the space would increase to an undesirable extent. The Authors have therefore designed methods by which it can be contracted and the volume of gas kept constant. But the brushes are not the only part which should be protected, for if a wire on the armature should break, or the insulation give way, or if anything should get between the armature and the pole-pieces, sparking might occur, and such a contingency should be provided for.

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There now remains the question of the switches connected with the motor, which will, of course, develope a spark on opening the circuit, when the current is flowing. This, in the opinion of the Authors, is a more serious difficulty than the former one, and they have endeavoured to meet it in two ways, namely, by diminishing, as far as possible, the tendency to sparking, and by arranging a switch which, even in the event of a spark, would be safe under any conditions likely to occur. The first idea that occurs is that by using a shunt-wound dynamo as a generator and a shunt-wound motor, the self-induction in the circuit is so far diminished that little sparking is likely to occur. But for many purposes, the conveniences arising from using a series-wound motor, as will presently be pointed out, are such that this method is in general to be abandoned, although the principle underlying it may be adopted. The reason of the diminished sparking with the shunt-wound dynamos and motors is, that the self-induction of the cable circuit is insignificant, and that of the armatures is also small, whilst the circuits of the magnetizing coils in both dynamo and motor, which have large coefficients of self-induction, are always closed through the armature. Thus, although on breaking the circuit the current in the magnet-coils tends to continue, it has a path of discharge through the armature of low resistance and of small self-induction. The Authors have therefore adopted the following plan: In the case of a series-wound dynamo they have provided a resistance-coil of small self-induction, which is always connected to the ends of the magnetizing coil, so as to form a path through which a current in the latter may continue, even when the main circuit is broken. In the same way, they have arranged the switch in such a manner that before breaking the circuit the coil of the magnets is short-circuited. By this means, the act of breaking the circuit reproduces the conditions which exist in the case of a shunt-wound generator and shunt-wound motor, and the only sparking which results is that due to the self-induction of the line and armatures. In order further to diminish this, the switch itself has, on its lower side, a resistance coil connected to the several points with which it makes contact, the wire being large enough to carry the current for the short time during which the switch is passing over them. By this means, even when the generator is short-circuited, the current is so far diminished that if the switch be moved slowly over the contacts, it is less than what has been termed the critical magnetizing current of the dynamo. The result is that by the time the circuit is open the series-wound dynamo has practically ceased to excite itself, the

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electromotive force and current are very small, and the sparking practically nil.

As an additional safeguard, the switch itself is constructed in the form of an air-tight box, which, in the same manner as the commutator covering, will exclude an explosive mixture for many hours. Although the Authors have never tried the experiment, they have reason to believe that the amount of gas which could be possibly contained in the switch is not sufficient, should it ignite, to blow the cover off; while the surface of contact between the cover of the base and the cylindrical hole, through which the handle passes, are sufficiently long to cool the escaping gas below the temperature of ignition. This switch is illustrated in Fig. 19. These precautions, which have been carried out successfully in practice, are, in their opinion, amply sufficient to meet all objections on the point of safety in connection with the application of electric motors to mining work.

Having so far dealt with the general question of the applicability of electrical power for mining machinery, and having indicated the methods adopted by the Authors in their designs, it is proposed now to illustrate the application of these principles by some actual examples. Full descriptions have been already given of the application of electric power to mining work under conditions analogous to those existing in ordinary power transmission installations above ground; for instance, Mr. A. Snell, Assoc. M. Inst. C.E., has elaborately described a large pumping plant working at Normanton,[1] and, in a paper previously mentioned, by Mr. G. Blake Walker,[2] the application to locomotive work of accumulators has been fully discussed. The Authors, therefore, propose to confine their attention to two or three illustrations of the use of electrical power, both in fixed plant and in machinery which is constantly moving from place to place whilst at work. For this purpose they have selected some dip-draining pumps, which are portable but are fixed whilst working; and they propose also to describe electrical coal-cutting machinery, electric coal-borers and electric rock-drills, as examples of constantly moving plant.

The earliest example of the application of electricity in mining work was its adoption by Mr. W. B. Brain, for draining a certain part of the Trafalgar colliery in the Forest of Dean.[3] An ordi-

[1] National Association of Colliery Managers, September 28, 1889.
[2] Transactions of the Midland Institute of Mining Engineers, vol. xi. p. 317.
[3] Proceedings of the South Wales Institute of Engineers, vol. 13, p. 277.

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nary horizontal pump was driven by a belt from the motor, which was fixed upon a permanent bedplate. The arrangement has worked well, and given satisfaction; but, in the opinion of the Authors, the use of belts in coal-mining work, unless under very exceptional conditions, is entirely out of the question, owing to want of space and the difficulty of keeping them in good working condition in dirty and wet situations.

In Figs. 1, 11, and 12, Plates 4 and 5, are illustrated two dip-draining pumps, a horizontal and a vertical form, designed by the Authors, and constructed by Messrs. W. T. Goolden and Co. In each case three-throw ram-pumps are used, the reason being that it is important in using electric motors that the load should be as regular as possible throughout the revolution. The pumps are mounted upon a bed-plate, which is extended to carry the motor. The motion is communicated from the motor-shaft to the pump-shaft by gearing. This method of reducing the speed is perhaps more noisy than the use of belts, but in practical working this is not of much importance; and, provided that the armature is properly constructed for the purpose, ample strength being given, and proper materials being used to avoid the result of the jar or shock, gearing may be confidently recommended. It requires no adjustment, and is so compact that the whole machine is self-contained, whilst, when the pinion on the motor, which is subjected to the greatest wear, is worn out, it can be replaced in a few minutes at a trifling cost.

Table III, Appendix, gives the data of one pump of each of these patterns, and shows the relative efficiency of the various parts, together with the size of rams. The gross efficiency is not very high, owing largely to the power used being small. But it was specially intended to produce a durable machine, suited for the rough conditions under which it was likely to be worked, and adapted also to be handled by persons who have not the necessary knowledge to keep any delicate mechanism in adjustment. These considerations necessitated the adoption of a large clearance for the armature, ample space for insulation, &c., all of which tended to diminish the efficiency. The motors, it will be observed, are of the Authors' enclosed type, the field-magnet coils being lagged with steel to prevent mechanical damage. These machines have, in some cases, run for many weeks, day and night together, with no attention beyond an occasional feeding up of the brushes and lubrication. This form of pump is well adapted for mines where the electric light is already installed, and in this connection attention may be drawn to a point which is

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worthy of note. In the use of electricity for motive power and for lighting, it has often been objected that the variations in the load upon the motor cause a considerable alteration in the lights upon the same main at some distance from the dynamo. The remedy for this is simple. By employing a well-governed engine, and compound-wound dynamo, the electrical pressure at the terminals of the generator may be kept constant; if then, a separate pair of mains is run for the motors, the pressure on the wires feeding the lamps is constant, whilst any variation at the terminals of the motor is not a matter of importance. These electrical pumps appear to meet every requirement of practical mining work, and have replaced steam and hydraulic pumps with considerable advantage.

Turning to the application of electricity to movable machinery, the Authors have for the last four years been constantly engaged in the design of electrical coal-cutting plant, and the results of the work done in this direction will now for the first time be published.

Although this use of electric power has only recently become an accomplished fact, it is interesting to note that the idea presented itself to Mr. Henry Wilde, F.R.S., of Manchester, one of the earliest pioneers in the development of the dynamo machine, as long ago as 1873, when he described the application of electric power to coal-cutting machines of various forms, in a provisional patent taken out by him in that year.

It was in 1887, so far as the Authors know, that the first machine was built for the purpose of cutting coal by electricity. It had a cutter of the bar type revolving on its own axis, a form which it appears was first introduced by Mr. Grafton Jones, and was driven by a motor designed for the purpose, and made by Messrs. W. T. Goolden and Co. (Fig. 6). The original experiments were conducted at the collieries of Messrs. T. and R. W. Bowers, and the conception of thus employing electricity is due to Mr. F. Mori, Electrician, of Leeds, and Mr. J. Blackburn, manager to Messrs. Bowers. Considerable difficulties were, as was natural, found in adapting power to conditions so novel, and so outside all ordinary experience; and, in order to obtain full information as to the obstacles to be overcome, the Authors devoted a good deal of time to practically working at the coal-face the various machines that have been constructed. These difficulties have been twofold: namely, electrical and mechanical. Fig. 6, Plate 4, shows one view of the original machine designed by Mr. J. Blackburn, containing the motor arranged to fit it. This was a three-coil

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vertical motor, adapted to work in a horizontal position, one of the side coils being removed. It was of 6 HP., and was driven by a dynamo having a normal output of 10 HP., the motive power being the engine of a hauling-machine, situated at the bottom of the shaft. The distance between the dynamo and the motor was about a mile.

The original dynamo and original motor were both compound-wound, the series-coils on the motor consisting of sufficient turns of thick wire to nearly saturate the magnets with the large current developed on first closing the switch; but when running at a normal load this series-coil had little influence on the magnetization, which was then affected by the shunt-windings; so that the regulation as to speed was almost as good as if the winding had been simply shunt. This arrangement is convenient as giving a good starting power, and at the same time ensuring satisfactory speed regulation; but in the case of coal-cutting machines the Authors have a decided preference for a series-wound dynamo and series-wound motor, for reasons previously described, namely, that when the motor is being stopped, by the insertion of a proper resistance, the electromotive force may be reduced nearly to zero before breaking the circuit; and further, if it is desired to handle the cables or to disconnect them, or to handle any part of the circuit of the machine after it is stopped, there is no liability to a shock should the insulation at any other point be defective. This is of great importance in a motor intended to be used by inexperienced miners, who are easily frightened, even by a moderate shock, so that they neglect to adjust the brushes, &c., even if they are not so far afraid that they will not work the machine at all. This first plant, which is still working satisfactorily, was, it will be noted, practically unprotected from dirt, dust, or explosive gases, and it was in connection with this that the Authors first devised their system of enclosed motors.

The next machine built by Messrs. Goolden is shown in Fig. 15, Plate 5, and in that case, as it was desired to cut into the coal at a height which was suitable for using direct driving without the intervention of gearing, the armature-shaft itself was made to carry the cutter-bar. The opinion, however, which the Authors now hold is, that although this method of working is quite feasible, it is on the ground of expediency not desirable. It is difficult to construct armatures with shafts large enough to carry the strain put upon them by a cutter-bar of the description used without cramping the space for wire and insulation.

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Figs. 10, 13, 14, and 16, Plate 5, show still later developments of this class of machinery, in which the cutter-bars are mounted on a separate shaft, and driven by steel double helical gear-wheels. The point to be noted is the combination of the electrical structure with the more strictly mechanical framework, thus providing the greatest amount of strength and electrical power with minimum weight and size. The dimensions of the heading along the coal-face are generally so small that it is only by great compactness that the use of these coal-cutting machines is rendered possible.

Fig. 9, Plate 4, shows in plan the general method of working. The machine, mounted on its wheels standing on the rails laid along the face, is adjusted by means of the turn-table and worm-gear, so that the cutter-bar points along the heading; the current is switched on, and the bar, revolving rapidly on its axis, is turned through an angle of 90° so as to enter the coal. The worm-gear and table being then locked, the machine is drawn along, by means of a winch and wire-rope, cutting its way as it goes. Automatic methods of winding have been devised, but that of pulling in by hand is probably the simplest in the end, and has the advantage of enabling the man at the winch to tell whether the machine is cutting in hard or soft material, and accommodate the rate of movement accordingly. Automatic winding-gear is usually arranged to work at a fixed speed, which must necessarily be that at which the machine will cut in the hardest material to be dealt with, so that with softer material the progress is obviously less than it need be.

The Authors have suggested an automatic winding-gear intended to obviate this objection. It consists of a ratchet-and-pawl motion, the pawl being under the control of an electro-magnet. Since the load on the motor is accurately measured by the current flowing through it, the magnet can be so adjusted, that if the load should exceed the desired limit, the pawl would be lifted out of gear, and the feeding stopped until the machine had eased itself again to its normal load, when the pawl would commence to feed it forward.

All the motors used for these coal-cutting machines are entirely enclosed as to every working part. The field magnets are lagged in steel coverings, the switches with their resistance frames are placed in iron boxes, and from the outside it would be difficult to see that the machine was an electric motor. Furthermore, precautions have been taken to thoroughly enclose the gearing, and all bearings and their parts into which grit can obtain access, and the system of lubrication is such that the oil

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passes from the armature-shaft to the cutter-shaft and thence is drained into the gear-box, which has an oil-tight joint, so that the gear eventually revolves in oil.

Fig. 16, Plate 5, shows a particular arrangement of machine, which was required to cut at any height from 9 inches to 33 inches from the road-level. This was effected by bolting to one of the pole-pieces a casting with two segmental slots. The cutter-bar was carried in a support moving on these slots, and by these means could be raised and lowered to any height, remaining at the same time in fixed relation to the armature-shaft from which it is geared.

It is interesting to point out to electrical engineers how the somewhat difficult problem of arranging this machine, so as to avoid the magnetic short-circuiting of the poles, has been met. The leakage from such extended pole-pieces is considerable, but not nearly so excessive as might at first sight be thought.

Several forms of armature have been tried in these machines, with both "drum" and "Gramme" windings, and the Authors are of opinion that on the whole, the "Gramme" armatures are best adapted for the work; the reason being that it is very difficult to secure the wire across the ends of a drum-winding in such a manner as to ensure their being positively driven, and in the absence of such positive driving it seems only to be a question of time when the insulation will become abraded by the excessive vibration. One form which has been much used in these machines is shown in Fig. 10. The armature-core is deeply notched to receive the coils, and when these have been wound in place the whole is covered with a layer of annealed charcoal-iron wire. By this means a notched armature, giving a low magnetic resistance in the air-space, is obtained, whilst the production of eddy-currents and consequent heating of the polar horns is avoided, and the armature is of a form which can be handled and laid on the ground, if necessary, without any damage occurring to the wire or its surface.

It soon became evident that the ordinary brushes used on dynamos and fixed motors were useless, owing to the excessive vibration to which the machines were subjected, whilst various forms having butt-contacts, in which the brush was pushed forward by springs, gave rise, both with metallic and with carbon blocks, to excessive heating, due, as far as can be ascertained, partly to the friction on the commutator, and partly to the inferior electrical contact thus obtained.

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Brushes of a type which has been successfully used in launch and tramway work, and was originally designed by Mr. Holroyd Smith, composed of blocks of metal carried by light steel fingers or springs, were also tried with similar results, and finally the Authors have adopted various forms in which the necessary elasticity is given either in the brush itself, or in a light steel back, there being however no movable hinge or knuckle which would allow it to chatter as a whole on the commutator.

The chief mechanical problem in connection with these coal-cutting machines has been: First:—What is the best form of gear to use? and Secondly:—What is the best form to give to the cutter-bars and cutters? As to the gear, the Authors have tried chains of every description and strength, and have had to abandon them all; they have also tried phosphor bronze gearing of ordinary forms, but have finally adopted, as working more smoothly and with less noise, and giving a maximum of strength, cast steel double helical wheels, shrouded nearly to the pitch line. By mounting one of such a pair of wheels in a manner free to slide to a small degree upon its shaft, the perfect alignment of the wheels is secured and the running leaves little to be desired.

Although the several machines illustrated in this Paper have been made to cut above the floor-level, at heights specially suited to each particular case, so as to work in the bands of shale or dirt and thus save the coal, yet the form with a bar-cutter is eminently suitable for cutting at the level of the floor itself, and the Authors have designed machines for this purpose, the rails being laid directly on the surface thus formed. The form of cutter most usually adopted in such cases is that of a large disk or wheel with the tools fixed into its periphery. This disk is carried on a bracket projecting from the side of the machine, and is caused to revolve by a pinion gearing into teeth either cut in its horizontal surface, or into teeth formed on its periphery, the teeth of the pinion being then made sufficiently long to allow the tools to cut clear at the bottom. The tools are spread out so as to cut the material clear of the disk.

Machines on this principle have been used with considerable success in several places, but the Authors consider the bar cutter is to be preferred for several reasons.

First, there is a considerable amount of difficulty in making a machine with a disk cutter to turn round so as to cut its own way under the coal, and in fact in most cases this is done by hand.

Secondly, when the tools are blunt, they have to be taken out and replaced by sharp ones while the disk remains in the coal,

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a matter of some difficulty in the confined space and with the small amount of light available. With a bar-cutter, on the other hand, since the bar is only held by four bolts at the coupling, it is turned out of the coal and a fresh one with a complete set of new cutters substituted, the other being sent to the bank to be reground.

Thirdly, if the coal or roof is at all tender there is a great tendency for it to fall as soon as it is undercut; to avoid this, wedges are inserted in the groove to keep it up, but the distance from the front of the cut to the back of the disk is considerable, and as a consequence the coal often falls before it can be wedged; this of course jambs the cutter, which then has to be dug free, involving a loss of time. Now with a bar-cutter the wedges can be inserted close behind the bar, only a few inches from the front of the cut, and the coal supported, so that even if it falls it cannot jamb the cutter.

Fourthly, a bar cutter can be made to bare to a greater depth, as much, for instance, as 5 feet.

Fifthly, in order to make an electric motor of sufficient power while the weight is kept small, it is necessary to run it at a fairly high speed, and therefore, to keep the gearing compact, the cutter must also run at a high speed. This is easily attained without any disadvantage with a bar-cutter, but is quite impossible with a disk-cutter, where the speed of the tools would be so great as to seriously heat and soften them. In practice the Authors run the motors at about 700 revolutions per minute, while the cutter makes about 500 revolutions per minute. On the other hand, the disk-cutters will draw more of the fine coal out of the groove than the bars will, but this advantage is not sufficient, in the Authors' opinion, to compensate for the disadvantages enumerated above.

The cutter (Fig. 17, Plate 5) consists of a long bar, either taper or parallel, fitted with a coupling to unite it to the shaft of the machine, and having arranged on it a series of steel tools. The bar, revolving on its axis, acts like a long milling tool, each set of cutters sawing its way through the material. The form used in the coal-cutting machine known as the "Economic" was a parallel bar, having holes in it, into which were fitted steel nibs secured in place by set screws. Some years ago Mr. Grafton Jones suggested the threading of star-shaped disks on to a square or polygonal bar, with a nut at the end to hold them in place. The cutter used by Messrs. Bowers in the first machine tried at their colliery, Fig. 18, Plate 4, was upon this principle. A series of

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star-shaped cutters made of cast steel having an hexagonal hole in the centre, were threaded on to a steel shaft, and secured by a nut at the end, the nut having cutters screwed into it, so as to clear itself. The result was satisfactory except so far as the wear of the points was concerned. In fairly soft or friable coal, it is doubtful whether they can be much improved; but in coal which contains much dross or is hard, the cutters are soon blunted, and the power required to drive the machine becomes excessive. After some experiments, in conjunction with Mr. Hans Renold, of Manchester, the form shown in Fig. 17, Plate 5, was devised.

The object in view was to provide a bar which would admit of cutters being used of a much higher grade of steel than was possible with the star-shaped castings previously mentioned: which should have more metal for removing heat from the point of the tool, thus preventing its softening and wear: and which should take, if possible, less power, and at the same time give a more steady cutting action, and remove the debris which it formed. To effect this, the bar is drilled with a series of holes, each of which is placed in a direction nearly at 90° to the next adjacent one, but differing so far from a right angle that one complete turn is made in the length of the bar; by arranging the cutter in this manner, a left-handed spiral is produced having a pitch equal to the length of the bar, which serves to equalize the cutting action, and also a right-handed spiral, which has a pitch equal to about $\frac{1}{8}$ of the length of the bar, and forms as it were a corkscrew to draw the dirt out of the cut. These holes are tapered to about 1 in 30, and pieces of round steel are turned to fit them, the heads being shaped to form the cutter, the exact nature of which depends on the material to be cut.

The proper form to give these tools is a question to which considerable attention has been devoted. Square-shaped, flat-faced tools were tried, of such a width as to overlap one another and remove the whole of the material; it was found, however, that the power required was excessive. Both square and pointed tools of various widths were then tried, with the result that the form indicated in Fig. 17 has been found to be, on an average, the best. This cutter is of a V-shape, and is placed in the bar with a gauge, so that the surface farthest in the coal is set in such a direction as to clear itself. The edge nearest the machine slopes across the cut, so that when the tool has entered to a depth of about $\frac{1}{8}$ to $\frac{1}{4}$ inch, a wedging action commences, and the ridge of coal left between two succeeding cutters is split off. By this means only about a quarter of the total quantity removed is

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actually cut away, the remainder being broken off by a splitting action, and the power required for working the machine has been reduced to one-quarter of what it was. Various speeds for operating the bar have been tried, but for fairly hard coal from 400 to 500 revolutions per minute is enough, although in soft and friable coals a higher speed may be adopted. The diameter over the points of the cutters varies from about 5 inches at the front of the cut to about 3 inches at the back. The tools when blunt are driven out with a hammer, and ground on an ordinary stone in a tool-holder, in which they are set in a taper hole, the holder being mounted eccentrically, so that in grinding the proper backing is given. These cutters are made of an exceedingly high quality of steel, which is tempered dead hard, so that it will easily scratch glass.

The average length that can be cut without changing the bar may be taken in hard coal to be about 40 yards, though as much as 80 yards, in hard gritty coal, has been effected without any stoppage. The blunting of the tools, however, when the edge is once really gone, proceeds rapidly, and out of proportion of the work done, and it is bad economy to force the amount cut to too great an extent. One man or boy attends to the winch, one man follows the machine, spragging and putting up props, whilst a third devotes his attention to the cutter itself, and to clearing the road in front of it.

The amount cut by the machine varies according to the nature of the seam, and the experience of the men working it; but it may be taken that on the average, all stoppages being included, 20 to 30 square yards per hour may be cut in fairly hard coal. As a matter of actual maximum performances, the following results may be cited. At Lord St. Oswald's colliery at Nostell, 55 yards were bared to an average depth of 3 feet 8 inches in seventy-five minutes, and lengths up to 20 yards, where the road is clear for running without stopping, have been often cut to this depth at the rate of a yard a minute. And at Messrs. T. and R. W. Bowers' collieries, where a less powerful motor is used, 110 yards have frequently been bared to a depth of 3 feet 6 inches in four hours. The length of cutter-bar usually adopted is from 3 feet 6 inches to 3 feet 9 inches, but it is a matter of interest that in a trial at Messrs. Briggs & Co.'s collieries at Normanton, a bar of 5 feet in length was used, cutting underneath to that depth, an amount exceeding considerably the best performance of any previous machine.

The actual HP. developed by the motor has varied in different

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cases from 6 HP. to nearly 15 HP., but in the Authors' opinion, it is a mistake to reduce too far the power available, and 10 or 12 HP. would seem to be a fair average amount for working rapidly and effectively, with a reserve enabling obstacles to be overcome, without straining the machinery.

Table IV., Appendix, gives the relative cost of cutting by machine and hand-labour in certain cases; but, although trials have extended over some time, it is perhaps too early to speak of what will be the ultimate saving effected by the use of these machines. Great difficulties have had to be overcome, apart from the electrical and mechanical problems, in the prejudice of the men, and in the resistance which they offer to the introduction of labour-saving machinery; and this has reached such a pitch in some cases that the miners have actually declined to work the machines, or to remove the coal which has been cut by them. These obstacles will disappear in time, but at present they form an element which has to be considered in estimating the cost of coal-cutting by electric power.

Electric Boring- and Rock-drilling Machinery.

An early example of the use of electricity in mining was the employment of the electric motor for working rock-drilling plant. This part of the subject has, although apparently simple, proved to be one of the most difficult to deal with; the reasons of this being—first, that the amount of power required is small, and, therefore, the advantage gained by electricity not so noticeable; secondly, that very powerful and complete drills, particularly percussive drills, are in the market; and, thirdly, that the use of machine-drills is generally resorted to in cases where the necessity for at once carrying out the work is very pressing, so that the contractors are less willing to try any experimental plant.

Drilling-machines may be divided into two classes: (1), rotary, and (2), percussive. Fig. 7, Plate 4, illustrates a form of rotary drill, complete with its own electric motor, and mounted upon trolley-wheels, applicable for use for coal or ironstone boring. The motor, the framework of which is made in one with the bed, is a small $\frac{3}{4}$-HP. enclosed mining-motor, of the Authors' design. The revolving drill-bar has a thread cut along its length working through a nut which is free to revolve except in so far as it is held by an adjustable brake-band. The result of this is that if the brake be slack no feed is imparted to the drill; if the brake be

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tightened, so as to prevent the nut revolving, a feed of $\frac{3}{16}$ of an inch per revolution, or any intermediate amount, may be given.

The power is taken from the motor-shaft by bevelled gear, giving a reduction in speed of $1\frac{1}{2}$ to 1; it is then transmitted by the vertical shaft and through a worm-gear to another pair of bevels. The total reduction in speed is from 1,600 revolutions per minute to 50 revolutions on the drill-spindle. This drill will bore a hole 2 inches in diameter in hard coal at a speed of 12 inches per minute.

It will drill in slate at the rate of about 3 inches per minute, but the principal difficulty in dealing with material as hard as slate is to procure a sufficiently satisfactory fixing to the roof and sides to prevent the whole drill from shifting and getting a cross strain upon it. It is therefore principally recommended to be used for coal or ironstone, where rapid sinking through moderately hard material is required. The drill takes about 10 amperes of current, at a pressure of 110 volts. Some experiments made to determine the power actually developed, through all the gearing and on the drill-shaft, show that the ratio $\frac{\text{mechanical power on drill-shaft}}{\text{electrical power}}$ is about 40 per cent.

For dealing with harder rock, diamond-drills, working in a similar form of machine, may be used, but the cost of maintaining diamond-drills is so heavy that in general little economy is effected by their use. Percussive rock-drills, therefore, are generally used for this purpose. The use of percussive rock-drills driven by electricity has, so far, been limited, one of the principal difficulties being the construction of a really suitable percussive action, driven by a rotary motion. Fig. 8, Plate 4, indicates the arrangement devised by the Authors for driving an Ingersoll rock-drill, by means of an electric motor. In order to diminish the weight of the drill, it is separate from the motor, which is mounted on a trolley, the connection between the two being made by a length of about 8 feet of flexible shafting.

The drill itself is well known. It consists of a bar lifted by a crank motion, connected to the driving handle by a ratchet and pawl, in such a manner that after the drill has been lifted by the connecting-rods against the pressure of a spring, as soon as the dead point on the top centre is passed, the spring forces the drill forwards, over-shooting the driving handle, which gears again as soon as the blow is expended. Two blows, or nearly so, are therefore given for each turn of the handle, which is designed to make sixty revolutions per minute.

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The driving-wheel is geared into a bevel pinion which is carried by an adjustable frame or quadrant and driven direct by the flexible shaft. The speed reduction is in the ratio of ten to one.

The motor, which is of the pattern previously described, and is entirely enclosed, is mounted on a trolley, and has a fibre pinion driving a gear wheel, which gives motion to the flexible shaft. The speeds are as follows:—Motor, 1,500, flexible shaft, 600, drill wheel, 60. This plant may be taken to represent the present position of electric percussive-drilling, but the Authors have been for some time engaged upon effecting the design of a new machine, doing away entirely with a separate motor, giving a direct percussive action and reducing the total weight to a considerable extent. The experiments upon this drill are not yet complete, and therefore, for the present, it will only be mentioned.

Dynamo for Transmitting Power.

Figs. 4 and 5, Plate 4, show in section a class of dynamo well adapted for use in transmitting power for electric mining-work, with pressure up to 1,000 or 1,500 volts.

The bed is of cast-iron, and a block in the centre of it forms the connecting yoke of the magnets, which are of the "inverted" type, and stand upon it. The magnet cores are of rectangular section, and are made of wrought-iron. The pole-pieces are of cast-iron, or in some cases are forged in one with the magnet-bars. The armature, which by preference, is of the "Gramme" type of winding, is composed of a number of thin sheets of charcoal-iron, insulated from one another by paper, mounted upon a phosphor-bronze spider, which is notched into the plates, and firmly keyed upon a stout steel shaft. The magnet may be shunt- or compound-wound, but in the case of transmitting power from a dynamo to a single motor, is preferably series-wound. The commutator is composed either of phosphor-bronze or of hard-drawn copper, insulated with mica. The brush-holders are of a special type, enabling the brushes to be fed through the holder and adjusted by a feeding-screw at the back, thus doing away with the necessity of loosening any bolts or nuts. This is valuable in case of long runs extending over nights and days together, such as often occur in mining work.

Special point is made in these machines of the ample clearance given to the armature in the pole-piece gap; $\frac{3}{16}$ of an inch a side is usually adopted, thus allowing room for wear in the bearings,

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and for the expansions which inevitably take place, and obviating the annoyance and delays caused by the armature rotating against the pole-pieces. The shaft and bearings are of large dimensions, compared with ordinary dynamos, for similar reasons, and the precautions thus taken of providing ample margins, not only in the mechanical factors, but also in the electrical design, have contributed largely to the success and freedom from accident which has marked the working of these machines in mining experience. Several of them have been running for periods extending over two or three years, in the hands of persons quite unacquainted with electrical matters, without any breakdown or repairs being necessary, and with very small wear upon the commutators.

Summary.

The instances described will be sufficient to show that:—

A. Electrical power is destined to become an important factor in mining mechanics, on account of—

1. The greater facility with which it can be used with machines which require to be moved from time to time as the work advances.
2. The great economy in first cost, and reduced cost of working owing to its efficiency being higher than that of compressed-air, or any other medium of power-transmission.
3. The smaller cost of maintaining the cables, as compared with piping, on shifting floors in roadways, etc.

B. That the methods described are sufficient to obviate all objections to the use of electric motors in coal-mining, either by excluding inflammable gases, or by constructions which allow of their safe combustion.

C. That the experiments, trials and practical work, extending over four years, show that—

1. Electrical pumps may be used with advantage and economy for mine-draining.
2. Electrical coal-cutters can replace hand-labour, with saving in cost, and increased production of coal.
3. Electrical drilling-machines are available in place of machines worked by hand or compressed-air.

While doubtless, on all these points, opinions may to some extent differ, and the particular methods adopted may be subjected to criticism, the Authors hope that the subject they have

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brought forward will be found of interest to the members of the Institution.

The electrical details of many of the machines described are due to Mr. H. W. Ravenshaw, Assoc. M. Inst. C.E., who has used considerable skill in adapting them to meet the conditions required. The Authors also have to express their thanks to Messrs. W. T. Goolden & Co., for placing drawings and results of tests at their disposal, as also to Mr. R. Hancock for his kind assistance in connection with the preparation of the drawings illustrating this Paper, from which Plates 4 and 5 have been prepared.

APPENDIX.

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APPENDIX.

Table I.

Size of Cable.	Brake HP. of Engines.	HP. Lost in Dynamo and Belting.	Per Cent. of Total HP.	HP. Given out by Dynamos.	Volts at Dynamos.	Volts at Motors.	Distance in Yards, Dynamos-Motors.	HP. Lost in Cables.	Per Cent. of Total HP.	HP. Put into Motor.	HP. Lost in Motor.	Per Cent. of Total HP.	HP. Lost in Pipes.	Per Cent. of Total HP.	HP. Absorbed in Friction in Pump and Gearing.	Per Cent. of Total HP.	Useful Work done in Raising Water.	Per Cent. of Total HP.
2. 19/12	200	20·0	10	180·0	670	550	3,800	32·0	16·0	148	15	7·5	16	8·0	22	11·0	95·2	47·8
2. 19/14	224	23·0	10	201·0	750	550	3,800	53·0	23·5	148	15	6·7	16	7·1	22	9·7	95·2	42·7
2. 19/14	256	25·0	10	231·0	860	550	3,800	83·0	32·5	148	15	5·8	16	6·2	22	8·5	95·2	37·1
2. 19/14	192	19·0	10	173·0	644	550	1,800	25·2	13·1	148	15	7·8	16	8·0	22	11·0	95·2	49·6
2. 19/16	209	21·0	10	188·0	698	550	1,800	40·0	19·0	148	15	7·2	16	7·6	22	10·6	95·2	45·6
2. 19/17	216	22·0	10	196·0	730	550	1,800	45·0	22·0	148	15	6·8	16	7·4	22	10·2	95·2	44·0
1. 19/14	72	7·0	10	65·0	674	550	3,800	12·0	16·6	53	8	11·2	3	4·2	13	18·0	29·1	40·5
1. 19/16	83	8·3	10	74·6	774	550	3,800	21·6	25·8	53	8	9·6	3	3·6	13	15·5	29·1	35·0
1. 19/14	67	7·0	10	60·0	618	550	1,800	6·6	9·8	53	8	12·0	3	4·5	13	19·3	29·1	43·5
1. 19/16	70	7·0	10	63·2	656	550	1,800	10·2	14·6	53	8	11·5	3	4·3	13	18·5	29·1	41·6
1. 19/17	73	7·3	10	65·6	680	550	1,800	12·6	17·2	53	8	11·0	3	4·2	13	17·8	29·1	40·0

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TABLE II.

System.	Brake HP. of Steam-Engine.	Brake HP. of Motor.	Distance from Engine to Motor in Yards.	Size of Cable or Pipe.	Price of Engine and Dynamo or Compressor.	Price of Cable or Pipe.	Price of Motor.	Total Cost of Plant, without Erection.	Efficiency.
				Ins.	£	£	£	£	Per Cent.
Electric . . .	15·4	10	2,000	7/8	210	192	95	497	65
Compressed air .	33·3	10	2,000	4	130	700	63	893	30

TABLE III.

Pattern of Pump.	HP. on Belt.	HP. at Terminals of Dynamo.	Volts at Dynamo.	Size of Cable.	Distance in Yards, Dynamo-Pump.	HP. Lost in Cables.	Per Cent. of Total HP.	HP. Lost in Motor.	Per Cent. of Total HP.
Vertical .	3·3	2·95	100	7/15	560	0·56	17·0	0·35	10·6
Horizontal	2·9	2·57	175	7/18	2,000	0·98	33·8	0·23	7·9

Pattern of Pump.	HP. Lost in Pump and Gearing.	Per Cent. of Total HP.	HP. Lost in Pipes.	Per Cent. of Total HP.	HP. in Water Delivered.	Per Cent. of Total HP.	Height Water is Forced.	Gallons per Minute.	Gross Efficiency Transmission.	Size of Rams.
										Ins.
Vertical .	0·6	18·2	0·165	5·0	1·260	38·4	170	24·3	43·4	3
Horizontal	0·47	16·2	0·600	20·7	0·288	10·0	19	50·0	30·7	3¾

TABLE IV.

RELATIVE COST OF CUTTING COAL BY MACHINE AND BY HAND-LABOUR.

Thickness of seam	3 feet.	
Cost of cutting, filling, &c., by hand .		2*s.* 6*d.*
Saving of coal by machine	20 per cent.	
Tons bared per shift	160 tons.	
Labour, steam, cutters, interest and depreciation at 15 per cent. . . .	0*s.* 3*d.*	
Cost of filling after machine, taking up floor, laying rails, &c.	1*s.* 3*d.*	
Total cost by machine		1*s.* 6*d.*
Saving over hand-labour		1*s.* 0*d.*
Saving in coal		0*s.* 6*d.*
Total saving by machine		1*s.* 6*d.*

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Discussion.

Sir John Coode. Sir JOHN COODE, President, hoped that the question of safety with regard to the use of electricity in coal mines as compared with other methods of conveying power would occupy a prominent place in the discussion. It was a most important point, and should be fully debated.

Mr. Ll. Atkinson. Mr. LL. ATKINSON desired before the discussion commenced to call attention to one of the cutter-bars on the table which was not described in the Paper. In order to avoid the grinding of the steel points and the expense of renewing the steel cutters, the latter were permanent and had chilled-iron points inserted in them which were nearly as hard as steel, and when worn out could be thrown away, being inexpensive. They had not had much experience with that form, but thought that it would lead to a considerable economy in the item of grinding cutters. He had been told several times lately that although the question of sparking on the motors had been treated in the Paper, they had not dealt with what would be likely to happen should the roof fall, or should the cable be broken from some other cause. The reason was that, although they had devised a mode of getting over the difficulty, it was so novel, that their experience of it did not justify them in placing it before the Institution. The form of the cable, however, was such that even should it be absolutely torn asunder by the breaking of the roof, there would be practically no sparking, and an arc was impossible. That, he thought, removed the remaining objections to the use of the electric cables in fiery coal pits.

Mr. Snell. Mr. ALBION T. SNELL said that during the past four years great progress had been made in the use of electricity in mining, and the General Electric Power and Traction Company, Limited, with which he was connected, had from the first been identified with the work. In 1889, in a Paper read before the Association of Colliery Managers at Wigan, he had described in detail several of the plants then at work,[1] and in 1890 at Sheffield, in a Paper entitled, "The Electrical Distribution of Energy over Extended Areas in Mines,"[1] he reviewed the whole subject and discussed the various methods of applying electricity. He then advocated the use of over-compounded dynamos and series or shunt-wound motors, so as to make the system applicable for both lighting and power, and also

[1] In the Library of the Institution. Tracts 8vo., vol. 488.

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Mr. Snell.

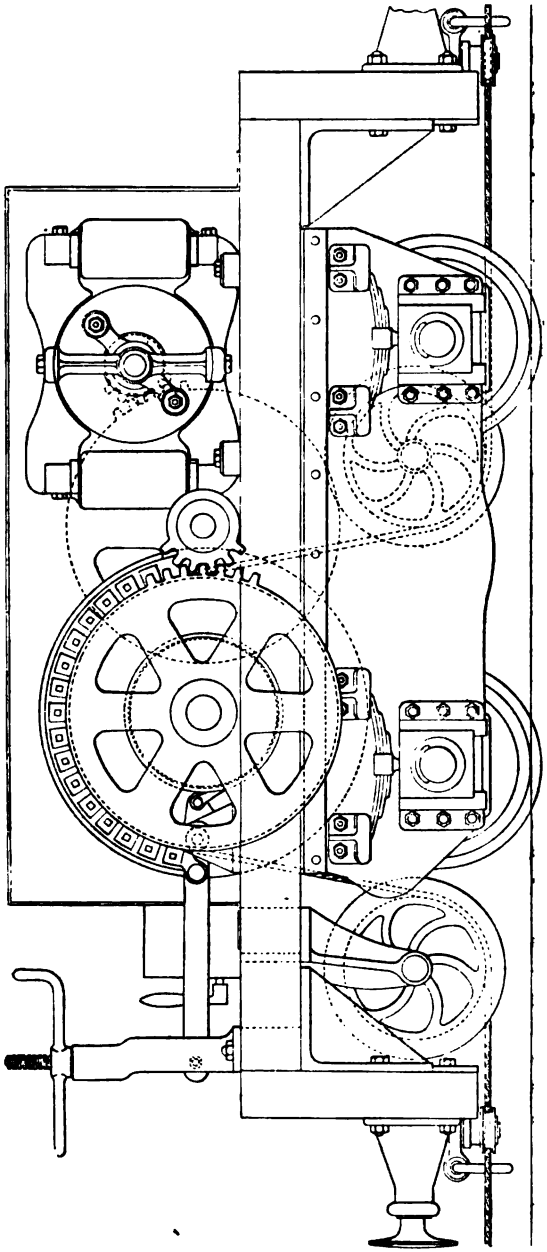

Fig. 1.

ELECTRIC LOCOMOTIVE.

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Mr Snell. to make it comparable to steam or compressed-air in point of adaptability. Since then his Company had laid down a number of installations, both at home and abroad, for hauling, winding, pumping, fan-driving and lighting, &c., with invariable success, and they had now in hand several which involved rock-drilling, coal-cutting, and pumping, as well as lighting. Before discussing the Paper he wished to draw the attention of the Institution to a new system of electric haulage for use on stiff brows in mines, by means of a cable or rope, fixed at either end and lying parallel to the road. The energy was supplied through wires above or beside the track. The system was introduced by Messrs. Immisch and Walker, and was the property of the General Electric Power and Traction Company. The cable was passed over a sprocket-wheel or a friction-clutch geared in a suitable manner to an electric-motor on a small trolley, the whole forming a light and compact electric-locomotive, *Fig. 1*, not depending for its grip on the friction between the wheels and the rails, but getting a direct pull on the fixed rope. The principle was similar to that employed for working floating bridges and barges. At the Wharncliffe Silkstone Collieries a brow about 500 yards long had been equipped in this manner, and the locomotive had been working successfully for about three months. The inclination of the road averaged 4 inches to the yard, and the rolling load was approximately 4 tons. The trolley carried a 10-HP. electric-motor, and weighed about 20 cwt.; which was unnecessarily heavy for that particular work. It ran in a headway of about 4 feet 3 inches, and the current was supplied by an overhead wire. The objection that had been raised with regard to sparking did not apply in this case. The motor as a whole was protected by a cast-iron covering. The rope was made of steel, and was about 1¼ inch in diameter. The friction-clutch was made by Barraclough of Barnsley. Experiments showed that a cable would give more satisfactory results than a rope on account of "slip" and consequent wear and tear. The work was previously done by five horses; but the strain was found to be so heavy that it was deemed advisable to change them every six months and put them to lighter work. The chief advantage of the system lay in the great tractive effort of the trolley in proportion to its weight—a point of considerable importance in mines with small headways and lightly laid roads. It was expected that the method would be applicable to many cases of underground haulage, but more especially to short and steep lengths on roads of otherwise moderate grades, where horses could be used for the greater part of the distance. Amongst the many interesting

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points referred to in connection with the application of electricity to mining, was the risk of igniting gas. As far back as 1888, when speaking on the subject before the Midland Mining Institute,[1] he gave it as his opinion, that under normal circumstances the sparks at the brushes of a motor would not readily fire gas, owing to their having a low temperature by reason of the large masses of metal in contact with them. His opinion was combated by several leading mining experts, and he therefore decided to make experiments to determine the point at issue. With that view he procured a wooden box about six feet long, with an internal cross-section of about a square foot. One end was blocked up and the other had a hinged door, so as to make an easy outlet for the probable explosion. In the centre a small motor and a gas-indicator were placed. Ordinary coal-gas was admitted from the closed end until the gauge registered an explosive mixture. The motor was then started, and the experiment watched through a glass window in the side. From time to time the sparking was increased by changing the position of the brushes, and the mixture of gas and air was varied through all ranges. It was found that even with excessive sparking the gas did not explode until the commutator and brushes had become heated to a far greater extent than ever obtained in ordinary machines. It followed that although under normal conditions a motor would be unlikely to ignite gas, yet if by any means the brushes and commutator became heated beyond a certain point, the exact temperature of which was not ascertained, the sparks would fire an explosive mixture of gas and air. It was unsafe to place an unprotected motor in an explosive mixture; and he did not think that under the ordinary mining regulations such an absurdity would ever happen, but it by no means followed that even in fiery mines a properly arranged motor should not be installed. He had had a considerable acquaintance with the mines in England, Scotland, and Wales during the past four years, and had noted the conditions of ventilation in both "long wall" and "pillar and stall" working; and he thought that by proper attention to details electricity might be safely employed in almost every colliery. The point to consider was the way in which the danger from sparking should be provided against. Obviously the best method was to have ample ventilation with a large reserve of power, so that in the event of "blowers," the draught could be increased. If the "faces"

Mr. Snell.

[1] Transactions of the Midland Institute of Mining Engineers, vol. xi., 1888, p. 347.

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Mr. Snell. were well swept with plenty of fresh air, and the goaf properly packed and looked after, no danger need be apprehended from electricity. But the motor itself could be protected in such a way that it would not fire gas. If it were fixed, say at a pumping or hauling engine, it could be boxed in and supplied with fresh air from the "intake." This arrangement did away with any sudden risk, and there would be ample time to stop the engine driving the dynamo, even if the men omitted to switch off the motor before withdrawing; and assuming a large "blower," working up against the main air-way, the gas would not make much headway against the relatively high velocity of discharge from the small orifice of the motor-casing, which would be farther increased by the heat of the machine. In the event of the ventilation being reversed through a fall (a very rare case), the heat of the motor would probably check the foul air until the current was shut off. He, personally, was inclined to lay the utmost stress on the necessity of providing ample ventilation by well-designed fans rather than trusting to any safety device in the motor itself; for in the latter case there would be the risk of faulty construction or accidental damage, and the personal equation of the attendants must always be an important factor. Roughly speaking, there were two main lines on which motors might be protected; first, by enclosing the whole of the armature, and secondly, by covering the commutator and brushes only. In the former case the volume of air enclosed was so large that, assuming an explosion, the cover would most likely be damaged and the outside gas fired. In the second case the volume of gas enclosed might be made too small to do any harm; but certain mechanical difficulties were involved, and as the armature was not shielded from external damage, a short circuit on the winding might, at any time, cause sparking in the unprotected area. He looked upon both the methods as good when the extent of the protection was properly understood. Messrs. Davis and Stokes' device of an inverted commutator increased the facility with which the fiery area could be limited. But the mechanical difficulties involved in the handling of the machine were considerably increased, and the armature, as a whole, was not covered in any way. The inventors endeavoured to treat the motor as a safety-lamp, the key of which was entrusted to the attendant, and so arranged that the motor could not work without the key ring being properly fixed in position. The idea was worthy of consideration, and no doubt would attract the attention of mining engineers; but it remained to be proved whether so complicated an arrangement was workable in a coal-pit. His Company was

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building a 25-HP. motor with an inverted commutator and internal brushes, but there would be some little difficulty in adjusting the latter, which he hoped to get over by using carbon brushes. Another question of importance with electrical work in mines was the installation of the mains. Too much stress could not be laid on the necessity for care in selecting the cable, and on the need of good honest work in erecting and jointing. In no other class of installation did badly designed or careless work so soon tell its own tale. He had used all classes of insulation for underground mains and had laid cables in both wet and dry mines. Speaking generally, it appeared that lead-covered cables, protected by an outer serving of braided and ozokerited hemp, were the most durable for wet pits, and should always be used in the shafts. They were also suitable for the main roads and levels, where the mains might be regarded as permanent; but for rough roads with falling roofs, or heaving floors and sides, he preferred an insulation of vulcanized rubber well served with braided hemp, as being more flexible. In all cases the ultimate success of the installation would depend largely on the method of erection, and the care given to details. In some roads he had buried the cables, in others carried them on insulators, and in many had simply cleated them to the props. In the shafts they should always be encased in strong wood troughing so as to protect them from falling stones, &c. The risks to be expected from the mains were two-fold. There was the very remote chance of an explosion, in the event of a cable being broken when transmitting energy; and there was also a possible chance of a bad "short-circuit" or "earth" causing trouble by firing timber. Considerable emphasis had been laid on each of these points by eminent mining authorities, who seemed, however, to base their opinions on theory rather than on actual experience. So far as he knew, the leakage of an electrical conductor had never caused any difficulty more serious than a short delay; and although he had seen timber charred in a pit top by a short circuit, yet there was no chance of a fire, because the electrical instruments showed immediately that a leakage had occurred, and the engineer in charge was at once on the alert. Indeed, the ease with which the supply of energy was governed and noted, formed one of the chief recommendations for the use of electrical power in mines. Electrical plant really entailed less trouble than steam- or air-machinery, and the men only required to get accustomed to it to appreciate its many advantages. It would not be out of place to say a few words on the possible limits of the use of electricity in mining. Evidently nothing was to be gained by it if the power could be transmitted

Mr. Snell.

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Mr. Snell. conveniently and economically by steam or rope; but whenever the distance became considerable these methods were more costly, as well as more troublesome, than either electricity or compressed air was. The Authors and himself were in agreement on that point, their experience coinciding with his own. But there were particular instances where electricity would always be preferred on account of the small space occupied by the cable and motor, as well as the little attention required, and the ease with which the plant could be shifted. And whenever water-power was available, electricity would prove the cheapest form in which energy could be transmitted. He had an extended experience in both main- and dip-pumping by electricity, and found in all cases a considerable gain in net efficiency over that obtainable by compressed air. At St. John's colliery, Normanton, electricity had been substituted for compressed air for main haulage, and main- and dip-pumping, with the result that the original boilers and engines had given rather more than twice the useful effect previously obtained. In Bohemia his Company had successfully transmitted by electricity the energy of natural water-power for winding, pumping, fan-driving, and lighting. They had several convenient forms of portable motors for coupling to Ingersoll percussion and rotary drills in somewhat the same way as those shown by the Authors. They were now building a new coal-cutter which he thought would do good service, being portable and at the same time powerful.

Professor Lupton. Professor ARNOLD LUPTON remarked that as a mining man he viewed the Paper with the greatest possible interest, and felt personally much indebted to the Authors for having brought so many valuable machines into the Institution. He happened to live in the neighbourhood where, he believed, the first electrical coal-cutter in the country was set to work, and had had the opportunity of seeing it in action on several occasions. He had made a study of coal-cutting machines. In 1865 he remembered going to a pit in Yorkshire about nine o'clock at night to start a coal-cutting machine, one of several introduced about that time. Since then a great many had been made and much inventive skill had been applied to their construction and design. That which he saw in 1865 was a pick machine. There had been rotary machines, and machines working with revolving bars, the same as the Blackburn cutter-bar, and the Goolden cutter-bar mentioned by the Authors. He had seen most of these, and they all seemed in his opinion to do their work well; and if they did not prove a commercial success it was not the fault of the inventors or makers, but was probably owing to some insuperable difficulty in the task

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Professor Lupton.

they were set to overcome. Twenty years ago he had been in a pit and had seen the machine worked by compressed air holeing at the rate of a square yard per minute. With the aid of a Richards' indicator he measured the exact HP. required to do the work. Some of the electrical coal-cutters, he believed, had equalled if not beaten that performance, but there was one thing to be said for those compressed-air machines to which he referred, namely, that some of them were still in use. He believed there was a colliery in Yorkshire where a great many rotary machines were at work successfully, and there was another where the pick-machine, invented more than twenty-five years ago, was employed. There was one point that he should like to mention. The Paper stated that the cutter-bar holed for a certain distance 5 feet under the coal, and that this could not have been done in any other way. Twenty years ago he saw a pick-machine that holed 5 feet under without difficulty, so that although the machine described in the Paper might be a good one and do its work well, it was not in that respect the pioneer. It was evident that the revolving cutter-bar lent itself to deep holeing with great advantage. He also thought that Messrs. Goolden, as far as he might venture to criticize their work, had introduced considerable improvements in the shape of the cutters. With reference to the question of safety in the use of these machines, the mines of this country might be roughly divided into fiery and non-fiery. The non-fiery were those in which gas might perhaps be found sometimes, but ordinarily speaking it was never seen, and blowers were never heard of. In those non-fiery mines there was a great opening for the use of electric machines. The Authors and also Mr. Snell had given much time and attention to the question of making a motor so that electricity might be safely used for the transmission of large amounts of power in fiery mines. Those devices might be clever. He thought that a coal-owner would not be likely to choose a manager who would get a dangerous machine into the pit and then cover it over to lessen the danger, but he would prefer one who kept as far as he possibly could away from any unnecessary risk. Therefore, without saying that the arrangements would not answer the purpose for which they were intended, he ventured to prophesy that in the course of the next twenty-five years those machines would not be introduced into fiery mines, and that for several reasons. In the first place, in the fiery mines of this country, as a rule coal-cutters were not wanted. The coal was frequently got by the gas, which blew it off, and the need for deep

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Professor Lupton.

holeing was not so great as in those mines where there was less gas, and the coal was often harder to cut. That led to another question—why should an electric coal-cutter or any other electric machine be used? As stated by the Authors, there was this strong reason, that the work could be accomplished with one-half the power, for a great deal less capital outlay, and for a much smaller working cost. Then it was supposed that a colliery owner would say to his manager, "Why do you ask me to put down expensive compressed-air plant when the thing can be done so much more cheaply by electricity? and if you cannot keep the mine free from gas I must get some one else that will." That was the dilemma in which a manager might be put if such statements as those in the Paper with regard to difference in the economy of electricity and compressed air obtained currency in the colliery districts. He should like to ask what evidence there was that electrical transmission of power was any more economical than compressed-air transmission of power? The Authors had quoted a Paper by Mr. Daniel, which was read in 1874, but they must remember that that was sixteen years ago, and although compressed air was not a novelty at that time, it was only about twenty-five years since it began to be employed to any extent in the mines of this country. There were gentlemen in the room who had seen it fifty years ago or more; indeed, he believed it was used in the last century. But twenty-five years ago there were only one or two spots in the kingdom where it could be seen in use. Since 1874 he believed there had been some improvements in the construction of air-compressing machinery. He should like to say that because in a colliery they did not have a very economical engine, it did not follow that one could not be made. At an average colliery were not they consuming three or four times as much fuel per horse-power as they all knew to be necessary? And was it likely that if they were not very careful about economy of fuel for a steam-engine, they would be much more so in the case of an air-compressing engine? He did not think that the instances of want of economy in individual air-compressors and motors in a colliery were any proof of what could be done by the system. It should not be forgotten with regard to those electrical machines, that the highest intelligence of the country, the utmost mechanical and scientific knowledge that the century had brought forward, was given to the production of them, whereas most of the air-compressing machines were made by mechanics who did not study the thing beforehand, but simply took the order and carried it out as cheaply as they could, and

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nobody knew whether the machine was bad or good unless some scientific man discovered that it was not giving such a good result as was expected by the happy and ignorant owner. *Fig. 2* was a diagram from an air-compressor. It would be observed that there were some zigzags on the top line, showing a pressure 15 lbs. higher than that in the receiver. It was not an economical

Professor Lupton.

Fig. 2.

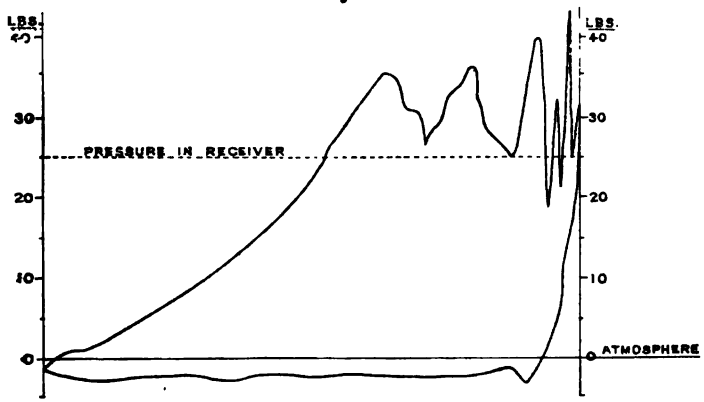
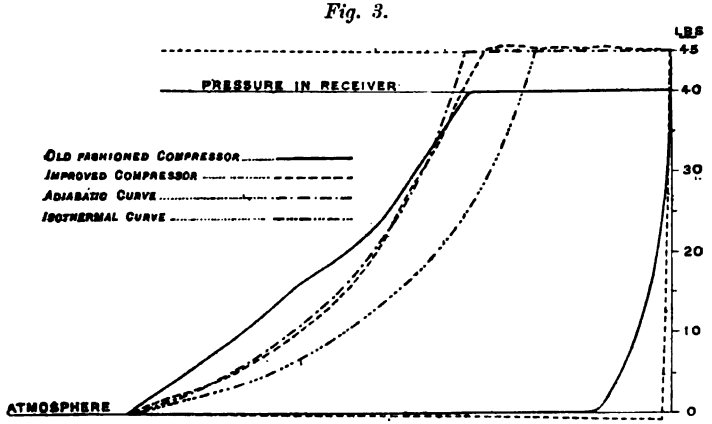


Fig. 3.



machine. In *Fig. 3* the full black line was taken from Mr. Daniel's Paper, showing the compression line. Comparing that with the curve given by the improved compressor, it would be seen that there was a great deal less waste power in the latter, the reason being that in the one upon which Mr. Daniel experimented the air as it entered the compressor was

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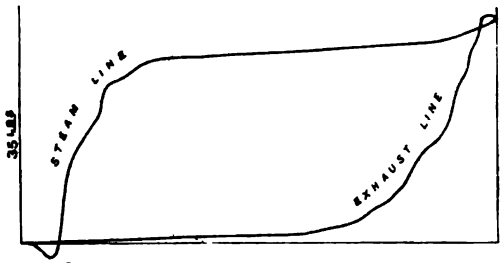
Professor Lupton.

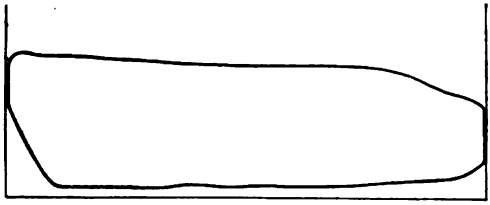
warm. The consequence was that the delivery was 25 per cent. short of what it should have been, and all the results that Mr. Daniel had given were 25 per cent. less than they might have been, simply through the heating of the inlet air. That difficulty had now been overcome. As much depended on the economy of the motor as on that of the compressor. *Fig. 4* was a diagram taken from a compressed-air engine before it was properly adjusted. The air was not admitted to the cylinder until about one-eighth of the stroke had been made; then the exhaust was not opened until about one-tenth of the return stroke had been made. The result

Fig. 4.



CONSUMER'S ENGINE BEFORE ADJUSTMENT.

Fig. 5.



CONSUMER'S ENGINE AFTER ADJUSTMENT.

was a diagram as bad as it could possibly be. By slightly altering the valve a diagram was obtained, with a proper cut-off and a proper exhaust, very much reducing the air-consumption (*Fig. 5*). They had been told what compressed-air could do, but the diagrams from the air-compressors had not been given. It had been said, "You can only get 20 per cent." because there were some bad examples. He would suggest that there should be a competition between the electricians and the advocates of compressed-air, each working a steam-engine, the power of which was to be taken to a distance of 10,000 yards, and used in lifting water to a given height.

In Table II the Authors had referred to the transmission of

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power to a cable of seven wires, No. 16 gauge. Mr. Brain, in the Forest of Dean, had used a cable of exactly the same length of nineteen wires, No. 16 gauge, for the transmission of the same HP., and he lost 20 per cent. of the power by the friction in the main. It was true that Mr. Brain used one-half the voltage that the Authors proposed. If they had 10 per cent. loss of the power put into the main they would still require a cable of nineteen wires, 16 gauge. The result was that the cost would be £100 more for the cable, without any insulators or fixing, than had been stated by the Authors in Table II. The cost of 4-inch pipes for compressed air had been given as £700. A 3-inch pipe would be ample for the HP. delivered, and if they took off £200 from the cost of the pipe, and put £100 on the cost of electric mains, the figures would be materially altered. He should like to know what was the price of the coal-cutting machine mentioned by the Authors as compared with that of a compressed-air coal-cutter. The Paper did not give any means of comparison, excepting with regard to the pumps. He had been told by a great authority that a small motor, say 2 or 3 HP., could not be worked at much more than 100 volts. He was also told that it was impossible to take electricity any great distance in a mine at a less voltage than 500 to do the work economically. Therefore, in order to drive several small motors in the mine at a distance from the shaft, they must have a transformer, which with continuous-current electricity absorbed at least 20 per cent. of the power. How did that affect the economy of the two methods? Then there was another equally important matter. Supposing a motor or twenty motors in a mine, all driven off one set of cables charged with electricity at a constant voltage; the motor was fixed to run at a given speed, and all the gearing was so arranged. It might be wanted to work a pump which had a constant load and therefore required a constant torque; the motor must always have a constant number of amperes in it to make it go. Suppose they desired to make it run at half speed; how could that be done? He had consulted a number of electricians who said, "Put in resistance." A resistance to reduce the speed to one-half absorbed half the power, and then what became of the economy? He had nothing to say against electrical machines, and he wished them all success; but when he heard statements that were not in accordance with his own experience, he thought he was justified in asking for some further explanation.

Professor Lupton.

Mr. Albert Grothe said that two years ago he visited several mining camps in the Western States of America with the object of

Mr. Grothe.

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Mr. Grothe. making himself acquainted with the application of electricity to mining work, and he ventured to think that a short account of what he saw would not be out of place. The direct impulse for the journey was given by a difficulty arising out of some mining operations in Mexico, which would only be thoroughly appreciated by those who had to take up and continue old deep workings in mines. Professor Lupton had laid some stress upon the supposed fact that there was no advantage, economically speaking, in the use of electricity over compressed air. Those who had experience of both knew better. But apart from the question of economy there was that of expediency, and many of the workings of which he was speaking were ill adapted to the ordinary means of transmission of power. Often there was no room for pump-rods or for steam- or air-pipes, and in such cases the flexible electric wire, so easily placed in position, so easily lengthened as occasion required, and so little in need of repair, offered great advantages irrespective of that of more economical working. In seeking the information desired he naturally turned his eyes to the United States for the obvious reason of proximity; but apart from that there was the important consideration that the Americans were far ahead of them in the application of electricity to the objects of daily life and industry. For every electric motor in use in this country three years ago there were said to be fully six hundred in the United States. He believed that there had been an advance in England since then, and that the disproportion was not now so great; but if they considered that at the end of August last there were in the United States two hundred and fifty-eight railroads, having a length of track of 1,927 miles, over which three thousand and twenty-four cars were run by electric motors, they would agree with him that the Americans were still ahead of this country. In the fifth-rate city of New Orleans electric power was delivered from house to house like water. There was, at the time to which he referred, a show-place on the Feather River near Oroville, California. The river there made a big bend 18 miles long, which at the narrowest part was only between 1½ mile and 2 miles across. The gravel was said to contain a large quantity of pay gold, and a company was formed for the purpose of washing and amalgamating it. A tunnel was driven across the shortest distance of the bend, and motors were placed at the lower end, so that the whole river was turned through the tunnel; and while thus supplying motive power for the different operations, left the river-bed itself bare and accessible. The hydraulic power was converted into electricity,

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Mr. Grothe.

which was led the whole 18 miles along the bend to perform the work which had to be done in connection with the operations. Unfortunately he had not been able to inspect this important plant in operation, as on his arrival the work had been stopped, and the machinery was in process of removal, not, he was told, on account of any failure of the electric appliances, but because the river-bed did not contain gold in paying quantity. He mentioned the circumstance to show how, in that country, large enterprises were often started on the spur of the moment, without sufficient foundation for ultimate success. In Virginia City, Nevada, the water which had spent its energy in driving a silver mill was taken through pipes down a shaft which communicated with the great Sutro Tunnel, and was made to act through ½-inch nozzles, with a head of 1,630 feet upon six Pelton waterwheels of 40 inches diameter, and each connected with a dynamo. The electricity thus generated at the bottom of the shaft was conveyed back to the mill on the surface where it drove six electric motors of 60 HP. each at a nominal expense, thus saving 360 HP. which formerly were absolutely wasted. At Aspen, Colorado, there was at that time only a small plant consisting of several hoisting engines driven by two dynamos of 27 HP. It worked so well that large additions had since been made, and there were now three dynamos for sixty arc-lights each, four others supplying an aggregate of 2,500 incandescent lights, and two power dynamos, one requiring about 60 and the other 120 HP. These drove several motors at a distance of about two miles at points underground to which it would have been most inconvenient to convey power by the older methods of transmission. In all those places, however, he missed one thing which had been mentioned by the Authors, namely the drill, and he also failed to find an electric sinking-pump. He understood the Paper to deal with the application of electricity to mining operations, and certainly miners would admit that a sinking-pump and a drill were among the most important mining appliances, and ought not to be left out when it was a question of the employment of electricity for such a purpose. The great difficulty was that so far electricity only gave a rotary motion, and to convert that rotary motion into a reciprocating one was not easy, at any rate while maintaining the special character of the drill. They had an application shown to them which was no doubt good in its way, but for practical work he certainly should not depend upon the machine which he saw before him. It would be necessary to have a drill which was capable of making something like 500 or 600

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Mr. Grothe. strokes a minute, not one which would be satisfied with 50 or 60, and with which no practical work could be done. He had recently driven a tunnel at the rate of 60 feet a week, which would have been impossible with such a tool. He had seen a similar thing in San Francisco, where instead of compressing a spring the piston moved in a cylinder containing air, which brought it forward in contact with the rock every time it was pulled back and released. In connection with this important subject mention ought to be made of a new reciprocating electro-magnetic engine by Mr. Van Depoele, which was described at the September meeting of the American Institute of Mining Engineers in New York. The leading idea was based upon the fact that an iron bar held near the open end of a coil of copper wire or solenoid, would be sucked into the solenoid the moment a current was sent through it, and that it would be released when the current was broken, and either drop out by its own weight or might be expelled by springs. The employment of springs in tools of this kind did not commend itself to the practical miner, but it would be observed that the inconveniences inseparable from their use were much less in connection with a reciprocating motion than they would be with a rotary one, and possibly a double solenoid, alternately attracting and releasing the iron bar, would enable the inventor to dispense with springs altogether. A further point of interest in connection with this new machine was that currents rising and falling in closed circuits were used, instead of alternating ones. This not only prevented the possibility of sparks being produced but provided for the regulation of the speed of the engine according to the work it had to do. He was glad to see that the Authors were on the track of a really useful instrument; and he assured them that as soon as they had produced it he should be very happy to put it into practice. There was still a wide field for the application of electricity to mining-industry and even domestic purposes, and he did not agree with those who thought that this power was yet too incompletely known to permit its use with safety. He maintained that as much was known about this particular form of energy as of any other, including the oldest of all—animal power. They could not grasp the mysterious nature of a horse any more than that of the electric current, but, if anything, had the latter under better control, and could apply it with greater precision. What they needed was not so much a greater knowledge of electricity as a greater readiness on the part of consumers to make use of it, and they were specially indebted to the Authors for having brought the subject before them.

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Mr. EMERSON BAINBRIDGE said the immediate point before them was the comparison instituted by the Authors between compressed-air and electricity. They had however gone a little farther, and had become exponents of a certain mode of cutting coal by machinery. He was now cutting about 1,000 tons per day by machinery, and therefore had some experience in that direction. Professor Lupton had spoken of a colliery manager being naturally disinclined to apply electricity underground in places where there was any chance of danger. They had not to consider this or that mode of providing an apparently efficient safeguard against a possible spark in a motor, but to bear in mind that they were dealing with human beings, in the dark and underground, and of a class that could not be trusted to keep delicate machines in order unless they were watched from minute to minute. Absolute security was therefore wanted in regard to sparking before a mining engineer would be justified in adopting electrical machinery in a fiery mine. His firm was using compressed-air, but he did not agree with Professor Lupton as to the comparative economy of the two systems. Mr. Snell's experience at a colliery in Yorkshire was important, because it supplied a comparison between two modes of doing the same work; and even if the compressed-air machinery in that case had been badly managed, and the economy mentioned by Mr. Snell were much reduced, it would still be considerable. There was often a great mistake made as to the importance of what was called the percentage of useful effect. He supposed that the Authors meant the work done as compared with the IHP. of the driving-engine. In coal-cutting the power exerted by each machine was 6 or 8 HP., and if with compressed-air 23 HP. was required to yield this amount, whereas with electricity 12 HP. might suffice, the difference in cost, with a well-arranged engine, would not exceed £30 or £40 a year, which was not worth considering in comparison with the risk of stoppages and accidents underground. In the case of compressed-air there was an almost perfect freedom from the risk of stoppage, which was a matter of great importance in a colliery. Although the useful effect might not be half so good with compressed-air as with electrical machinery, fewer repairs would be required. If a colliery manager could have the assurance of being able to carry on his electric work without an electrician, he would be much more inclined to use these machines than he was at present. The Authors had referred to one method of coal-cutting, exemplified by the radial bar on the table. According to Mr. Bainbridge's experience it was best done in an entirely different way. The most widely known Mr. Bainbridge.

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Mr. Bainbridge.

systems were those of the wheel working slowly outwards at about 30 revolutions, and the wheel working inwards and making about 200 revolutions per minute, and he ventured to say that either of those methods would accomplish more, in regard to quantity and regularity of work, than the machines described by the Author. In the one case by pressing a bar forwards against a solid mass there was a constant tearing away of the coal; whereas in the other case there was less resistance and probably more work was done with a given amount of power. Whatever might be said about the difficulties of applying electricity to coal-cutting would not apply in the same sense to pumping. As a general rule, a pump was fixed for a longer or shorter period, but a coal-cutting machine was constantly being moved about, and there was the risk of dirt and dust flying about, and damaging the machinery and the various parts of the gear which carried the electric current, especially where several hundred yards had to be traversed. In the case of pumping there could be no comparison between the cost of compressed-air and electricity. In a few days he should have a pump raising 50 gallons a minute 400 feet high at a distance of 2¼ miles from the engine; and the first cost would be less than one-half that of compressed-air. With regard to drills, he did not think that they would ever be of any service for coal. Machines were now made for drilling coal by hand which would drive a hole 3 feet deep in about two and a half or three minutes, and the speed mentioned in the Paper was but little better than that, and as the hand-drill cost about 30*s.* or 35*s.* there was not much scope for improvement in that respect. He thought that there was an excellent opening for the application of these machines to driving stone drifts and sinking shafts and that kind of work. He should be glad if the Authors in their reply would refer to some place where such machines had been in practical use. There was at present so little literature available for mining engineers as to the application of electricity underground that he felt greatly indebted to the Authors for their contribution to it.

Mr. Parker.

Mr. Thomas Parker (of Wolverhampton) remarked that as the Authors had referred to the plant at the Trafalgar Colliery, with regard to which exact data were to hand, some few statements respecting it might be of interest. The first installation was put down in 1883 by Messrs. Siemens. It was only 1½ HP., but the colliery manager was so favourably impressed with it that in 1885 an order was given to Messrs. Elwell-Parker to put down 2½ HP. plant. That machine ran until 1887, at which date an order was given for a 20-HP. motor in addition. That was used for pumping,

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and there was also a small plant for ventilating. The data were published in 'Industries,' December 9th, 1887. The distance was 2000 yards, and although the motor and dynamo were manufactured five years ago, the efficiency obtained was 40 per cent. of the brake HP. in water raised, and the cost per HP. in water raised was 0·2*d*. That was now a matter of history, and it would compare with the best compressed-air plant which could be put down for the purpose. In working the machines it was extremely advantageous to be able to know what was going on below by the instruments above ground, and the exact amount of work being done by the pumps was indicated by the voltmeter and ammeter in the engine-house. As was stated in the Paper, they used belts in that particular case, the reason being that they wished to get the motors a little further away from the pumps, which were constantly breaking the joints and scattering the water about. They were now making motors which were proof against getting wet, but he did not think it advisable to run any risk so long as it could be avoided. If the loss incurred in the leads was assumed to be 10 per cent., they could easily obtain at full load an efficiency of 75 per cent. of mechanical energy delivered at any point, however distant. With regard to a question asked by Professor Lupton implying that at varying loads they were compelled to use the same amount of energy, under ordinary circumstances the electrical motor had the power of regulating the amount of energy it received by the amount of resistance which was imposed in the way of work. As one proof that compressed-air was beginning to lose favour with mining engineers where they were satisfied with the safety of the application of electricity, he would state that he had just received orders from a colliery company in his neighbourhood, after careful trial on a smaller scale, to replace compressed-air plant with a 60-HP. installation for electrical transmission. With reference to the suggestion that there should be a competition to determine the merits of electricity and compressed-air, he could only say that he would be glad to enter into the competition at any time that might be selected. He had frequently devised machines for use in dangerous places, but he had never been able to find a colliery manager who was willing to undertake the risks, and he did not care to do so himself. It was not a question solely of sparking, but of accidents which might happen to the armature or any parts of the motors or cables; and the machines to be employed in dangerous places must be under the supervision of persons who were acquainted with their laws. If the cables were run in iron piping, in which also the switches

Mr. Parker.

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Mr. Parker. might be enclosed, and if that iron piping was made to carry a supply of fresh air from a safe portion of the mine into a chamber loosely covering the motor, there would be very little risk indeed if ordinary care were taken. It had been said that a high class of intelligence was needed to superintend those matters, but the same was true of compressed-air machinery when it was first made, and probably before long plenty of labour would be available to prepare and handle electrical installations. They were greatly indebted to the Authors for their Paper, and he believed that engineers were now on the eve of a very large application of electricity.

Mr. Brain. Mr. FRANK BRAIN thought the Paper was a most valuable contribution to the subject of electricity as applied to mining. With reference to the plant that his firm had put down at the Trafalgar Colliery in the Forest of Dean, he might mention that they had increased it three times, and had had no trouble with it. With the first installation they carefully boxed up the cables, anticipating that a fall of the roof might damage them. When they put in the second and third installation they did nothing of the kind, as it was found that there was no necessity for it with a fairly insulated cable, to which proper attention was given. It was a non-gaseous mine, and the trouble from the falling of the roof, &c., was very small. He had closely followed the discussion with reference to the means taken to prevent the explosion of gas. As a practical man, he looked upon the machine as well fitted for putting into the hands of the miner. There were many mines where it could be used without danger from fire-damp, and he thought that it was one of the most practical in the market. It was so strongly made, and so closely boxed up, that it appeared almost impossible to injure it. It was much better, as the Authors had shown, to protect an armature going at a high speed, in a machine which was intended for use in a dark mine. That he regarded as a distinct advance, apart from the question of gas. The Authors stated that the construction of the machine was such that they could ensure its running in explosive gas for two hours with perfect safety. If so, that was all that colliery managers required, and so far from suggesting that a non-explosive compound should be introduced, he would say, "Stick to your text and prove it, and we shall be satisfied." The matter of efficiency had exercised his mind. In papers which he had read on the subject before the British Association and the South Wales Institute, he prominently introduced that question. He might mention that Mr. Parker had made use of some figures which were a misprint, the real figures not being quite so satisfactory.

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Mr. Brain. At the meeting of the South Wales Institute there was a large number of practical men who had used compressed-air plant in their collieries, and some of the makers of it were also present, and the matter came up prominently for discussion; but he was disappointed to find that no reliable data were put before them. There were many opinions, but no practical figures were forthcoming. When the President, Mr. Colquhoun, who had a great deal to do with colliery plant, summed up, he said he had had nothing to do with electric motors, but he must confess that, so far as his experience went, the efficiency of compressed-air machinery never exceeded 25 per cent. Mr. Brain had recently spoken on the subject to an eminent engineer, who was describing a large compressed-air plant with all the latest improvements which he was putting down; and on asking him what efficiency he expected, he said that he hoped to get 40 per cent. A short time since a large colliery owner whom Mr. Brain knew asked his manager to furnish him with indicator diagrams of the compressed-air plant at all his collieries; and the efficiency was found to be 17 per cent. In the case of some modern machinery belonging to one of his friends (who had nothing to do with electricity), the average result obtained from the diagrams was 18 per cent. That was pretty strong evidence as to the present day efficiency of compressed-air plant.

Prof. Forbes. Professor GEORGE FORBES differed from the Authors as to the danger of using the machinery which they suggested in fiery mines. He believed that in 1878 the largest employers of coal-cutting machinery in the country were the firm of Merry and Cuninghame. They were then using compressed-air to drive it, and were getting an efficiency of about 25 per cent. He was asked to look into the question of applying the electrical transmission of energy to the purpose. He accordingly worked out a plan, and was only deterred by a consultation with Mr. John Cuninghame, the manager of the Company, who with himself came to the conclusion that the danger of sparking was so serious that it was utterly impossible to employ electrical motors for coal-cutting machinery. And he still said, after carefully reading the Authors' Paper, that even with the precautions therein mentioned, it would be dangerous to introduce the machinery described into a fiery mine. Various theoretical reasons had been given why it was perfectly safe. First, it was said that in the ordinary way of using an electric motor the temperature of the spark was so low that it would not fire an explosive mixture. He could not believe that that statement was made with experience of what an

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Prof. Forbes. electric motor would do. It was certainly true that in the ordinary way of working an electric motor under the most perfect conditions there was hardly any spark at all, and it might be that there was only the red spark which did not produce the oxidation of copper, and was therefore of a lower temperature than that required to cause the ignition of an explosive mixture of fire-damp and air. But in a large number of cases they certainly did get a spark of a higher temperature at the brushes, and he hoped that no one would believe that in a fiery mine it would be safe, from the reason suggested, to adopt a motor, or that sparking of the brushes could not possibly explode a mixture of fire-damp and air. The Authors further said that, even if an explosion could be so caused, they had enclosed the commutator in a casing by which such a result was rendered impossible. They maintained that there never could be any serious accumulation of marsh-gas in the casing, because the spark of the commutator would be continually burning it up; in other words, that the sparking was really a safeguard against an explosion. He thought they had utterly failed to recognise the fact that if the machine were left for a considerable time the gases would accumulate inside the casings, which would be a very serious matter when the machine was started again. Moreover, the Authors stated: "It is not likely that any electric motor will be placed in such a position as to be worked continuously in an explosive atmosphere for a longer period, at the outside, than two or three hours. The casings with which they are provided are tightly fitted at all the joints, many of them being packed with rubber, and it is not likely that an inflammable mixture could penetrate to a dangerous degree within that time." That was all very well, but if the machines were left unemployed for a considerable while, the gases would accumulate in the casing. Moreover, the coal-cutting machines, of which he chiefly spoke, were used in the most dangerous part of the whole mine—at the working face, where they might strike a blower at any moment and have a large outburst of explosive gases, which would be a very serious thing if they depended simply upon the protection afforded by the casing. Having originally stated that the temperature of the spark was not sufficient to ignite the gas, and having then said that if the temperature was sufficient to explode it they provided against the danger by putting the whole commutator, and perhaps the whole machine, into a casing, the Authors remarked (evidently foreseeing that it would not be accepted as sufficient precaution by engineers) that they would admit carbonic acid into the casing. He could not believe that that suggestion

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was really put forward as likely to be adopted by coal-miners. Prof. Forbes.
Was it conceivable that the miners would continue admitting carbonic acid into those casings for a long period when they knew that there was no fire-damp about, and would they not be perfectly certain to cease doing so? And it would be when the supply of carbon dioxide was omitted that the blower would be struck, and a large amount of fire-damp would be admitted. It was said in the Paper: "These precautions, which have been carried out successfully in practice, are, in the Authors' opinion, amply sufficient to meet all objections on the point of safety in connection with the application of electric motors to mining work." He wanted to know what those words meant. Had the machine been tried in an explosive mine, where there was known to be an explosive mixture of gases at the place where it was used, or (what was much more important) had it been worked in a chamber filled purposely with an explosive mixture of fire-damp and air? He certainly should not be willing to sit in the chamber while the experiment was being made, and he should be glad to know from the Authors whether they had made such an experiment themselves. Then there was another serious reason against the adoption of electric machinery in fiery coal-mines, namely, the danger of the fraying of the insulation, or of the actual severance of the mains by picks, &c. He could conceive no place in which it was more difficult to ensure perfect insulation than a coal-mine, in consequence of the damp which was often experienced, the dirt, the grit, and especially the darkness, which rendered the cables more liable to be trampled on and damaged. There was no place where there was greater danger of injury to the insulation, and if only for that reason, he should consider it very dangerous indeed to put down an electric plant in a fiery mine. If, however, by the adoption of extraordinary precautions, the mains could be made with a fair certainty of preserving their insulation, he should still object altogether to the use of the machines described in the Paper, owing to the danger of sparking at the commutator, and the results which might happen therefrom. He thought it might be interesting to the Institution if he mentioned some results which had been obtained from a different type of electric motor, which entirely obviated the defect to which he had referred, namely, the Tesla motor, which he believed was discovered simultaneously by Nikola Tesla and Professor Ferraris. It had no commutator, and no collecting brushes on the armature, and the armature, as an electric unit, was totally distinct from the rest of the circuit; and

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Prof. Forbes. there was no possibility of sparking there. It required, however, that there should be not simply one single current, but two, and was therefore driven by means of a special dynamo, with four poles and two circuits on the armature, so arranged as to give currents differing in phase by an interval of a quarter of a period. Three wires were required for the mains, one for each current, and an intermediate return. The motor consisted of a similar arrangement—four pole-pieces, and an armature which was wound with wire and short-circuited upon itself. The result was that the current circulated round the field-magnets of the motor in such a manner as to cause the polarity of them to rotate continually in one direction round the armature, and by doing so to make the armature to revolve in the same direction. In this way without any commutator whatever they were able to get powerful mechanical effects. He thought it was worth while to mention the matter, because he supposed he was one of the few who had had an opportunity of testing these machines, which he did a year ago at Pittsburg. At that time they were not being made larger than about 5 HP.; they worked extremely well. He was only able to get a rough idea of their efficiency by the means at his disposal, but he knew that they were fairly efficient. The chief difficulty was that of getting sufficient torque, or twisting power, when the current was first put on; but by an ingenious device that difficulty had been overcome. He believed that they had been made of larger size since the time to which he referred. They had been largely used in Pennsylvania in coal mines, and he thought they were certainly the type of machine that would naturally be employed in places where there was danger from fire-damp.

Mr. Taylor. Mr. JOHN TAYLOR said he did not intend to take part in the discussion with regard to electrical machinery generally, but he was able to give some facts which would be of interest, because they were the results of working mines upon a considerable scale during a period of several months. He referred to some gold mines in California, the property of a company of which his firm had the management. They had been abandoned for some years, in consequence of the impossibility of working them to a profit by steam-power, the ores being of low grade. The matter was brought to his notice two years ago by Mr. G. Cullen Pearson, who was interested in the mines during the period of their working by steam-power. Mr. Pearson saw the future possibility of the transmission of power by electricity, and secured, in addition to the interest he then had in the mines, water-power at a

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distance of about two miles. This was utilized by a Pelton wheel, 87 inches in diameter, and capable of developing 125 HP. with 400 miners inches of water under a pressure of 110 feet. This wheel drove a Brush generator of 100 HP. The current was transmitted to the mines, which were at an elevation of 1,400 feet above the power-station, and a distance of 10,890 feet (just over 2 miles), by a No. 3 insulated copper wire less than a quarter of an inch in diameter. The wheel and the generator were capable of developing 125 HP., but they were not working up to that. The exact length of wire to complete the circuit was 22,588 feet, or 4 miles and 1 furlong. At the mines there was a Brush motor working up to 60 HP. actual. It drove a ten-stamp battery, and three Huntington mills besides, equal in all to a forty-stamp battery, and there was also a large rock-breaker. In addition, all the mills and buildings were lighted by glow lamps by the current taken direct from the transmitting-wire. The power required for running the machinery as at present used was from 41 to 43 electric HP.; there were ammeters and voltmeters placed both at the power-generating station and at the mills by the Brush Company who put up the plant, and they were guaranteed by them to be correct. The electricians present would be able to give their opinion as to whether there could be anything questionable in the results given by these instruments. Mr. Pearson had himself made numerous observations by means of a telephone from the generating-station to the mines, and Mr. Taylor had received from him particulars of one taken on the 12th of January. At the power-generator there was registered 29 amperes at 1,250 volts, equal to 48¾ electrical HP. The current at the mills at the same time was 28 amperes and the pressure 1,100 volts, equal to 41¼ electrical HP.; so that practically they were receiving at the mills from 83 to 85 per cent. of the HP. generated as actual working energy, at a distance of over 2 miles. They were confidently told by the electricians who put up the machinery that a wire two sizes larger would give from 2 to 5 HP. additional; they might therefore talk about 90 per cent. of the HP. at a distance of more than 2 miles. Mr. Pearson had mentioned a variation of from 1½ to 2 per cent. in the power delivered, which it appeared was dependent upon atmospheric conditions. It might be easily understood that there was a larger efficiency in cool dry weather than on a warm, damp day. The electricians of the Brush Company stated emphatically, after the work had been going on for some time, that they might safely reckon upon 70 per cent. of the HP. at a distance of

Mr. Taylor.

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Mr. Taylor. 12 miles. The experiment was not a small one; the work had been going on since August, day and night unceasingly. They had a good deal of trouble at first, but after everything was in order they went on without a single interruption. The most remarkable thing was the small amount of wear and tear, which appeared to be confined to the copper brushes, and the copper segments of the commutators. Mr. Pearson had given the whole expense of the renewals and for oil at only $25 per month, which was, of course, a mere trifle. He had proved, during that period of five months, that he required no skilled men. Two miners had been instructed, and they attended solely to the machinery where the Pelton wheel and the dynamo were working. Up at the mill there was no supervision whatever of the motor beyond one of the men going in to see that the oil cups did not run empty. The machinery, Mr. Pearson stated, was entirely under control, and in all his experience he had never had to do with a motive power which could compare with it for economy, cleanliness, steadiness, and the ease with which it could be handled. Between the 1st of August and the 31st of December the machinery had dealt with 19,000 tons of rock. The gold was extracted at the remarkably low average cost for mining and milling of 50 cents.—or 2*s.* 1*d.*—per ton, beating, as far as Mr. Taylor's experience went, any record even where there was water-power close to the scene of operations. It would be readily understood that there was an enormous field opened up for working mines and many other industries under similar conditions. Mr. Pearson's statement was a remarkable one, and he placed it before the Institution as the actual result of a large operation over a considerable period.

Dr. Foster. Dr. Le Neve Foster remarked that the point that specially concerned the mines in his district was the discovery of an electric drill, which would bore holes for blasting, and naturally, when he heard that such a machine was at work in the neighbourhood, he made an effort to go and see it. It was the one represented in Fig. 8. He was greatly disappointed on arriving at the mine to find that it had not turned out a success, and had been sent away. The reason of its failure would, he hoped, be given by the manager of the slate mine, Mr. Roberts, who saw the experiments made, and had come from North Wales to speak on the subject. The expression used by the Authors, "as hard as slate," seemed rather inappropriate, because to a miner slate was a comparatively soft rock, and it ought not to go forth to the world that it was considered by them to be one that was difficult to bore in. The

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Authors had also referred to the diamond drill, stating that the expense of the diamonds was so heavy as to make the use of that machine unfitted for boring holes for blasting. It was perfectly true that the cost of diamonds was high, but it was not prohibitive. An account was given in the last *Jahrbuch fuer das Berg- und Huettenwesen*, a Saxon mining annual, of a diamond drill which was in successful use in Germany for that purpose. The writer found by experience that in such rocks as the crystalline schists, gneiss, greenstone, porphyry, clay-slate, and granite, the cost per foot bored was two-fifths of a penny for diamonds alone. It was true that that was a high charge, but taking the results of actual work, it was found that, although the cost of driving tunnels had not been diminished, yet it was possible to drive them twice as fast for the same money as with hand-labour. In the case of a soft rock like slate a less expensive material than diamonds might be adopted; he believed that emery might be used with success. He should be glad if the Authors or any one else could give some information about the Edison percussive drill, which appeared from the drawings to be a handy instrument. He thought the thanks of miners generally were due to the Authors for giving so much information as to the use of electricity in mines. The Paper was one that would be read and re-read by them, and he hoped that one result of it would be the utilization of a large amount of waste water-power in the district in which he resided among the hills and valleys of North Wales. Dr. Foster.

Mr. C. Warren Roberts said that a question had been asked by Mr. Bainbridge as to where the Authors' percussive drill had been in actual use. A percussive drill had been tried at the slate-mines belonging to Messrs. J. W. Greaves and Sons, of North Wales, for whom he was Engineer. The plant put down by them was erected mainly with a view of rock-drilling either by rotary or percussive drills. They utilized a stream of water drawn from reservoirs. It averaged 300 feet per minute, and passed over wheels at various elevations, developing from 100 to 120 HP. before it arrived at the turbine, which was now used to generate the electric power. The first drill tried was of the Authors' rotary type, which was not made specially for slate, and did not work successfully in it, although it had answered well for coal. Slate, as Dr. Le Neve Foster had said, was very soft, yet it was tough. The rotary machine did not succeed perhaps for more than one reason. It did not seem to bite into the rock; and if it did there would be a difficulty in getting the dust from the pulverized slate out of the hole. Afterwards the proprietors Mr. Roberts.

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Mr. Roberts. of the mine tried a percussive machine, the ordinary Ingersoll drill, driven by a flexible shaft, like that in Fig. 8, Plate 4. There were various mechanical arrangements in that drill which were faulty. The principal thing was that the legs could not be fixed up with any security, there being a want of rigidity about them. The flexible shaft kicked a good deal while revolving, causing a jerk in the frame, irrespective of the concussion due to the working of the drill itself. The back leg of the tripod on which the instrument was fixed was not sufficiently rigid, and the vibration caused it to shift about. In practice he found that the length of the feed, which was only 8 inches, was much too small, necessitating the changing of the drill two or three times, and it was not easy to get the old drill out and the new one in place. Other mechanical difficulties were met with in small matters, such as pins breaking, the failure of the feed-gear, and the automatic twisting of the feed. They were now hoping to get a drill mounted on a central column fixed on a trolly, which could be screwed up to the roof, so as to ensure rigidity; while by various simple mechanical arrangements the frame of the drill could be moved into almost any required position, thus saving much time in fixing the machine for boring fresh holes. The motor also would be fixed on the same frame, thus doing away with the flexible shaft. At the present time the difficulties were mainly mechanical, and they wanted a drill to work more directly from the motor than the one they had been able to get. There was no difficulty with regard to sparking in slate mines, because there were no dangerous gases generated. There was undoubtedly a large field for the application of electric power to mining purposes, especially in the Festiniog district, where the supply of water was ample, and the mines were amongst the largest in the world. Some of the openings were from 100 to 150 feet high, 50 feet wide, and 200 feet long, and an idea of the extent of the workings might be gathered from the fact that in those with which he was connected there were over 20 miles of roadway.

Mr. Smith. Mr. Holroyd Smith said the figures which had been given from America with reference to the transmission of electrical energy appeared to him to be altogether too good, and he desired, as he had done on one or two previous occasions before other societies meeting in that room, to lay stress upon the necessity of stating the particular point from which such measurements started, and the point at which they ended. When he heard of electrical energy transmitted for 2 miles with an efficiency of 85 per cent.,

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it was altogether too good, at any rate for him to accept. If they took only the electricity that went out from the generating dynamo, and compared it with that received at the end of the cables by the motor, then he admitted that 85 per cent. was easily obtainable: it meant that 15 per cent. was lost in the wires themselves, and for a distance of only 2 miles such a loss, without some further justification than the saving in copper, was not to be commended. He assumed that the Authors when speaking of their percentage of efficiency, and comparing it with that of pneumatic machines, were referring to the power exerted by the steam-engine and the power given out in actual work where it was received. He had had several times to deal with statements as to the transmission of electrical energy, and when he had given his figures some of his hearers had said that they were too low, while others had stated that they could do a great deal better. His reply was that if he measured in the way that some persons did he could get the high total efficiency claimed by them. The question was one not only of scientific but of commercial importance. They ought to make it almost a matter of conscience to speak clearly, not only amongst those who were familiar with the different modes of measurement, but especially when talking to the outside world who would be the purchasers and users of the apparatus and instruments. On a question of transmission the Authors had stated that there was little difficulty in obtaining 50 per cent. of the power expended in the engine. He wished to ask whether that meant indicated HP. or the power given out by the engine. It was a little risky, if they wanted to define clearly what should be the efficiency of any system, to be dependent upon the efficiency of the engine employed, an item that seemed to be left out in some statements. His own experience had not been such as to enable him to say with certainty that he could expect an engine to lose less than 15 per cent. in itself before it began to give anything to outside work. It was necessary to know what the amount of this loss was before a proper comparison could be made between the various systems of transmission. [Mr. H. B. Atkinson said that the horse-power referred to in the Tables was brake horse-power.] The brake horse-power given out, and the actual work done, were to his mind the points from which they ought to start and at which they ought to end in any calculations of that kind. Previous speakers had offered some criticism as to the style of dynamo employed by the Authors for their work, and he thought that any one who had had experience of coal-mining would agree with Professor Forbes in wishing, as

Mr. Smith.

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Mr. Smith. far as possible, to avoid sparking. What had struck him as rather paradoxical was, that Professor Forbes had started with a very strong and absolute prohibition of the employment of electricity in coal mines, and had afterwards elaborately described a particular kind of motor that had recently come under his observation in America. He thought there was no electrician present who would not much prefer an alternating-current motor if it could be economically constructed, and could be made reliable not only in working, but in the very important point of starting. Professor Forbes did mention some difficulty on that score, which he said had been overcome. He was interested to find that the Authors and several other electricians, whose knowledge and experience in these matters were much greater than his own, had, through a series of experiments, been led to a conclusion which he had himself arrived at intuitively some years ago, namely, that the Gramme type of armature was better suited for rough work than the drum type. At meetings of that kind their duty was not merely to criticise, but as far as possible to make suggestions. He would offer one with regard to the percussive drill. He did not know how far it might be practicable, but it had helped him out of a difficulty some years ago. He had been preparing for a lecture upon the action of the wings of birds and insects in flight. He wanted to illustrate a theory that he had formed upon that question, but his difficulty was how to imitate the movement of the wing of the insect without any complication of mechanism. He did so by alternately compressing and releasing air in a cylinder, the pressure being transmitted through a tube to a similar apparatus attached to the model. Possibly, in the rock-drill, the required blow might be produced by allowing the motor to force and to suck air in a similar way. Perhaps some of those who were engaged in this work might find it worth while to make the experiment.

Mr. Crompton. Mr. R. E. B. CROMPTON wished to call attention to a diagram prepared by Messrs. Smith, Beacock, and Tannett, of Leeds, who, he believed, had made the first electrical coal-cutting machine (*Figs. 6* and *7*) about three years before the date mentioned by the Authors. It consisted of an oscillating arm furnished with cutters, and mounted on a vertical spindle, so as to oscillate through a stroke of from 5 to 8 inches. The short end of the lever was worked by a pair of electro-magnets, to which the current was applied alternately by a very crude form of commutator. The result was that a vibrating motion was given to the arm and the coal was cut. The difficulty was the imperfect

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knowledge of electrical matters in those days. He did not doubt that the Authors had acted wisely in adopting the revolving cutter-arm which they had shown. The next point to which he

Mr. Crompton.

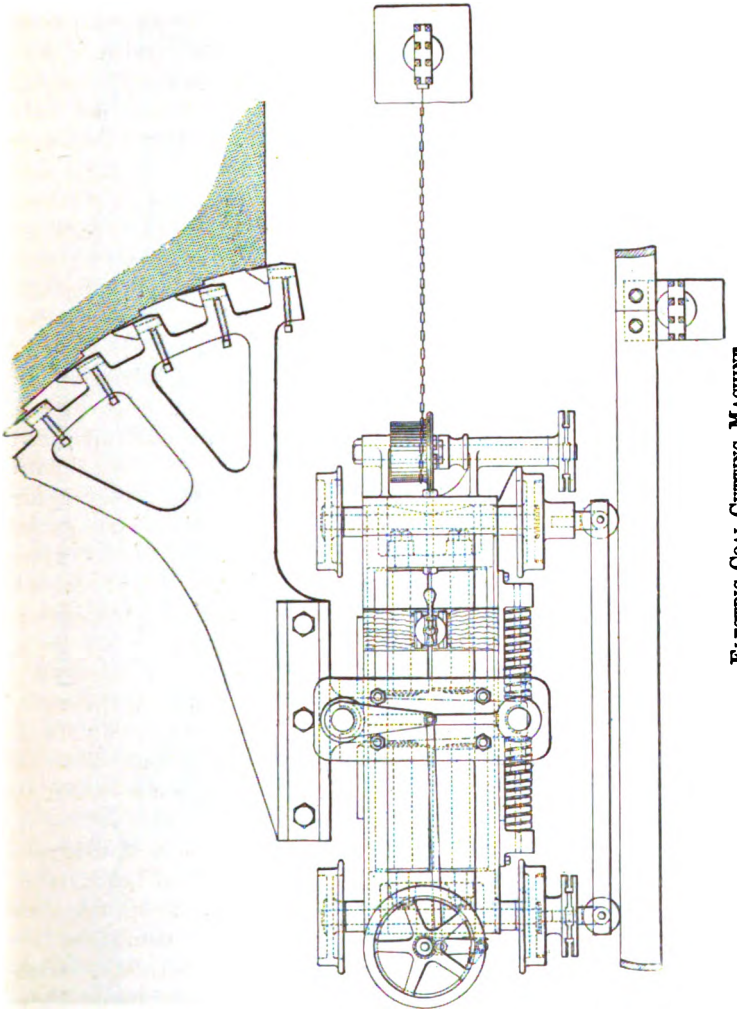

Fig. 6.

ELECTRIC COAL-CUTTING MACHINE.
Scale ½ inch = 1 foot.

wished to draw attention was the moderation of the language used by the Authors when comparing the efficiency of electrical transmission with that of compressed-air transmission. He agreed with several speakers that nothing was to be gained by over-

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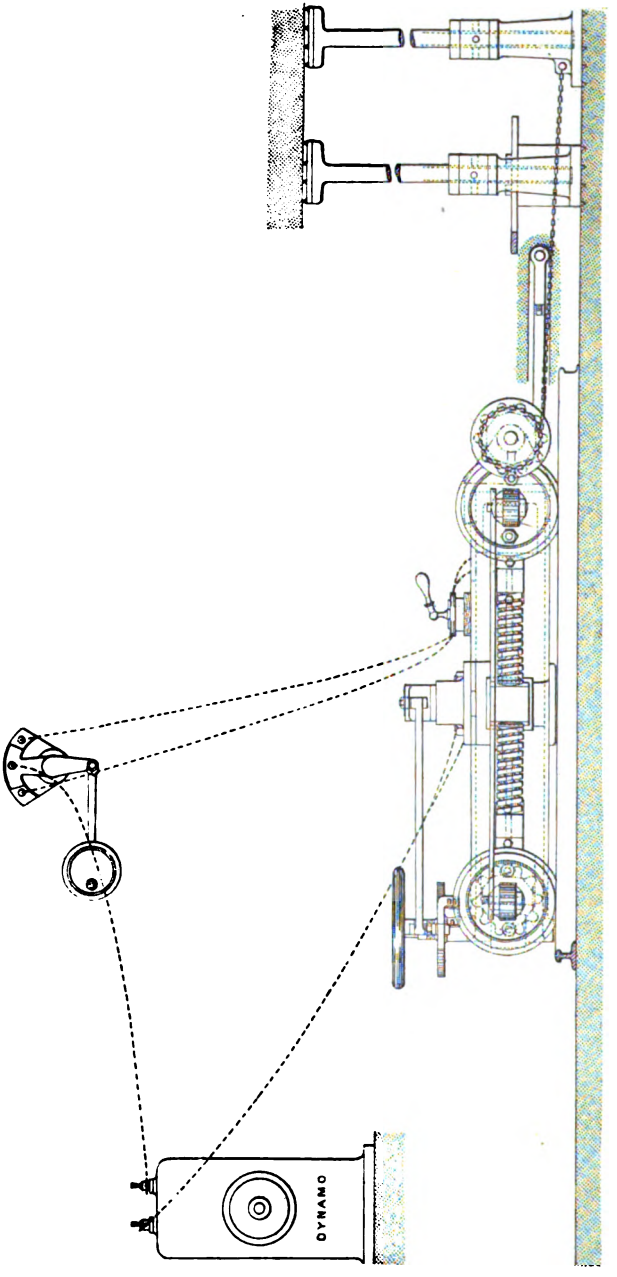
Mr. Crompton.

Fig. 7.



ELECTRIC COAL-CUTTING MACHINE.
Scale ½ inch = 1 foot.

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stating the case, but he thought that those who were conversant with the use of electricity would agree with him that the Authors had, if anything, erred on the side of moderation. He was surprised to hear them say that their percentages were taken on the brake horse-power. He thought that they had taken them on the indicator diagram, and even then he was prepared to substantiate them. He was quite certain, therefore, that they had allowed an ample margin, and that electrical engineers ought to be able to carry out, and more than carry out, all that had been said with regard to the transmission of power up to the distances named. Professor Lupton had thrown down a challenge to electrical engineers which he believed had been taken up by one or two gentlemen present. But it had already been taken up in a much more practical form, namely, by the supersession of air-transmission plant all over the country. This was being done to a large extent in South Wales, and he believed that in a few years the transmission of power by compressed-air would be nearly obsolete. Reference had been made to the cost of repairs for electrical-transmission plant as compared with compressed-air plant. The one complaint that the owners of the latter had made to his firm was the great expense of the up-keep. It was costly in two ways—first, on account of its being so inefficient: that portion which answered to the generating plant—the steam-engine and boilers and the air-compressing pumps—was from two and a half to three times as big as was necessary for the electrical plant, and the expenses of the up-keep were proportionately increased. Then there was also the interest on the money invested, and not only was the prime cost greater, but more space was taken up by the machinery. He had carefully gone through the figures presented by the Authors as to the comparison of the first cost of air-transmission plant with electric-transmission plant, and he unhesitatingly stated that they were correct and moderate. They had left out one important item that ought to have been put in, namely the cost of the boiler-power necessary, which, in the case of air-transmission plant, was nearly three times as much as was required for electrical transmission. He had heard with considerable interest the remarks of Professor Forbes as to the extraordinary dangers which he foresaw in the use of electrical machinery in fiery mines. Professor Forbes had apparently overlooked one important matter. It was true that, however carefully they might guard against the danger of the communication of the sparks inside the casing to the explosive gases, there was some risk. He admitted it, but it would always be so wherever

Mr. Crompton.

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Mr. Crompton. machinery was introduced into mines. They could not work any kind of coal-cutting machinery without the possibility of the steel points coming into contact with some material harder than the coal, and so causing sparks. Explosions might be produced in that way. He thought however that the risks from such a cause were greater than they would be from sparks communicated from the commutator in carefully devised casings such as the Authors had recommended. Some of the drawings of the casings, he thought, might be improved upon. He considered far too much space for explosive gases was given, and that it might be reduced to such an extent that the danger would be extremely small. With reference to the drill question he agreed with a previous speaker, who wanted something simpler than the Ingersoll drill, driven whether by a flexible shaft as shown by the Authors, or, in a way which he himself preferred, by a simple rope on to a V pulley. He would like to have a direct-acting percussive drill, with a quick, short stroke. They should in fact imitate some beautiful drilling machinery which was shown in the Paris Exhibition two years ago, driven by compressed air, giving he did not remember how many thousand strokes per minute. The stroke was infinitesimally short, but the machine was able to cut away the surface of the hardest substance at an astonishing rate.

Mr. A. Sopwith. Mr. ARTHUR SOPWITH considered coal-cutting one of the most important subjects connected with electric mining-machinery. They had arrived at a great state of perfection in motors and had certainly got considerably beyond the experimental stage with coal-cutters. The Authors had mentioned one special type as the best, namely, the rotary cutter-bar; but so far as the application of electricity was concerned, whether the machines worked with a rotating disk, or with a band with cutters, it was practically the same. Under certain conditions they could be used to considerable advantage; but they required a fairly even floor, and a good roof, so that there might not be too much intervention of timber. They also required, in the case of the rotary cutter-bar, a band of coal or shale somewhat in a state of tension, which considerably assisted the action of the cutters. The converse of those conditions frequently existed, and would greatly militate against the working of the machine. They might often have to cut in dead tough material in which very little progress could be made. Again, the timber necessary for the roof sometimes made any continuance of working in the line of the face impossible. In America there were machines worked by

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electricity which obviated some of those difficulties. Instead of going along in a continuous line, a short length only was taken at a time, and a cut was made of a certain width and depth; then the machine, which could be clamped to the rails, was moved forward, and another cut was made alongside; or if anything intervened it could be placed further on, and the remaining part cut out. The principal advantage of this method was that it obviated the necessity of continuing along the face. The application of motors to work percussive or pick machines might also be easily understood. He was about to make a suggestion, which might be open to criticism, but he understood that something on the same lines had been done in America. It was practicable from a mechanical point of view; and the question he wished to ask was whether there was any real difficulty in carrying it out from an electrical point of view. Mr. Crompton had said that a machine which would give a very great number of blows, let them be ever so small, would probably be a very good type, and he agreed with that view. The point which was looked after very often in coal mining was that of having a machine which would do a great deal of work. He felt certain that a much lighter machine, although at a great sacrifice of power, would gain so much in portability and convenience, that in the long run it would do as much work as a big one. The principle of what was known in America as the Electro-Magnetic Reciprocating Machine appeared to him to be certainly applicable to drills. In it, a bar was drawn into a coil by the action of a current, and brought back again either by springs or by its own weight when the circuit was broken. The great point was the question of the make and break; but if a generator was constructed by which rising and falling currents were created in a closed circuit, the work was done without any possibility of sparking. He thought there should be no difficulty in designing a coal-cutter upon the same principle. It might be said that it would not be easy to construct a machine which would do anything like the same amount of work; but then it would have all the advantages of simplicity, and the absence of movable parts subject to wear and tear. Although in practice it might appear that the wear and tear of coal-cutting machinery worked by motors was not very great, it could be easily understood that quick rotating and heavy armatures working along an uneven floor must be a source of continual expense; but if percussive action could be employed in working coal in as simple a manner as he understood it had been in America with rock drills, he thought they

Mr. A. Sopwith.

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Mr. A. Sopwith. had arrived at a solution of the difficulty. A person not familiar with the subject would be struck with the large amount of power which was lost in the transmission of the electrical current. No doubt when the use of electricity became, as in all probability it would in a short time, universal throughout mines, and it had to be conveyed long distances, the question would assume greater importance. There was one thing which he thought most engineers would object to, namely, having high tensions down a mine. Although the transforming system might be carried out, it seemed to him that it would lead to great complications. But he thought there was no place so convenient for the economical carrying of a current as a coal-mine, especially if it happened to be dry. In his case he had used, although not for conveying power, a quantity of old iron and old wire-rope instead of copper, the resistance being only $\frac{1}{25}$ ohm per 1,000 yards, and the cost, including insulation, the same as that of a copper cable of $\frac{1}{16}$ of good insulation. The relative economic value of iron to copper was as 5 to 1, so that at all events there was room for allowing five times the amount of current at the same expense. He mentioned it because it had impressed itself upon his mind, especially as he had tried an experiment with laying wire-ropes side by side on the floor of a coal-mine, and found that practically there was no leakage at all, the coal-dust being a perfect insulator. Certainly great economy might be effected by the use of such conductors for conveying the current to centres of distribution in a mine.

Mr. Walker. Mr. SYDNEY F. WALKER wished to offer his hearty congratulations to the Authors, and the firm they represented, on having been the first properly to grapple with the question of the electrical transmission of power in mines. He thought that nearly all those who had studied the question had felt that, before it could be on the same footing as compressed-air, hydraulic power, and other systems now in use, they must have self-contained apparatus. If a mine-owner had some pumping to do in a place where he could get a steam-pump, he had only to connect his steam-pipe to it. Until the introduction of the present machines, they had to put down a pump with a motor and gearing separate, and he thought that these inventions would prove a marked advance in the transmission of power by electricity. As to the important question of sparking, he agreed with the Authors up to a certain point. He had repeatedly expressed the opinion, before Mining Institutes, that the sparking at the commutator was not dangerous, and would not fire gas, and he still adhered to that view, for the following

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reasons. First, he had discharged ordinary coal-gas over an old series commutator ten years ago, and could not get the slightest sign of ignition. Then it should be borne in mind that in order to produce ignition, the spark must pass through the gas, and he would ask whether a revolving armature did not create something like a vacuum in the neighbourhood of the commutator, which would keep the gas out. He had another and a much stronger argument which had come to him only recently. Petroleum gas, he understood, was much more inflammable than ordinary coal-gas. The chief engineer of a petroleum steamer had told him that he had a dynamo working in their pump-room, which was always full of petroleum vapour, into which it was dangerous to go with a naked light; but there had not been the slightest sign of ignition. At the same time Mr. Walker realized with the Authors, that if there was any feeling amongst mine-owners that the danger existed, that feeling must be respected and provided for. He did not think that their cover was of the slightest value, for they could not bottle up a spark: the proper course was to get rid of it. There were two points where the spark might be—one at the switch, and the other at the commutator. It appeared to him that there was no reason why the switch need be in gas at all. It could be put in the engine-house, or at any convenient point, with an ordinary electric-bell signal between it and the motor station. With regard to the motor itself, his view was that where the gas had to be provided for, and there must be no sparks, there were three ways out of the difficulty. If the alternate-current motor proved itself a success, that was evidently the machine of the future for all work of that kind. The second way was the one which Mr. Sopwith had mentioned, and which he thought could be arranged very simply, and worked by an alternate dynamo from the engine-house or by reversing-gear in the engine-house near the dynamo. The third way was to reduce the spark at the commutators below the firing point. He thought it was clearly proved by experiments that had been made, some by himself and some by Mr. Mordey and others, that it was not a spark *per se* that ignited the gas, but a spark of a certain energy; there must be a current of about 10 amperes, and, at any rate, a pressure of 2 volts. If, therefore, they could construct a motor so as never to have a spark with a pressure of 2 volts at the brush, including self-induction and everything, it would be harmless. That was simply a question of construction and of size. Like Mr. Sopwith, he strongly advised that the tension in a mine should be kept low. He was aware

Mr. Walker.

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Mr. Walker. that, at the present moment, both pumping and hauling were being done with 300 and 500 volts, and no serious harm had resulted. He thought it should be remembered that those were selected cases; when they came to regular everyday work they might and probably would have accidents. It was not that a man might be killed with the shock, but that it might throw him into a position, say in front of a train of loaded trams, where he might meet with a severe accident. He might get, even from a comparatively low voltage, a very severe shock, with his wet boots, wet socks and hands, in a wet mine. He knew an instance in South Wales in which a man received an extremely severe shock from a voltage of only 160. As to the gearing, the whole thing appeared to him to lead to low voltage, which would enable them to go at a low speed. Everyone knew that the gearing was one of the difficult points that electrical engineers had to deal with, and for that reason, and also on account of the danger of shocks, he strongly advised that the motor should be made as large as possible and with a low voltage. Though the copper in the cables would be larger, the interest on the money spent on it would be more than made up by the decreased cost of maintenance.

Mr. Bolton Mr. Reginald Bolton said that Professor Lupton had classified the mines of this country into the fiery and the non-fiery. From a coal-miner's point of view that was all right, but Mr. Bolton ventured to divide the subject into two larger heads—soft-rock and hard-rock mining. Coal-mining came under the former head, and from the hard miner's point of view it was a comparatively simple affair. Those who had had to deal, for example, with the tin cable of Cornwall would know what he meant by hard-rock; and such materials required special consideration. He had ventured to give a few diagrams with reference to the question of percussive rock-drills in order to illustrate the particular duties required of them under the conditions which he had mentioned. He would not at that late period in the discussion enter into a detailed description of each particular machine, but the diagrams would show the main features of the rise and progress of percussive rock-drilling, from the ancient production of Samuel Miller in 1806, taken from the drawings accompanying his specification, which constituted the earliest form of percussive drill of which he could find any mention, up to those machines now in use throughout the world in all kinds of hard mining. The rock-drill referred to in the Paper was essentially what was described as a hand power-drill, and from the

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point of view of mining for metals, it was nothing but a toy. There was no possibility under such conditions as he had described of using a rotary motion in the heading of a mine or in driving hard tunnels. The Ingersoll machine, to which the motor had been shown attached, and which had been exhibited in the room, would, he imagined, bore at the utmost about 2 inches per minute, with a hole 1½ inch diameter. The duties of a rock-drill should amount to at least 10 inches per minute, with a hole 1¾ inch in diameter, tapering to 1¼ inch at the bottom. That was an amount of work with which the machine mentioned in the Paper would not be able to cope. But there was a form of electrical rock-drill which had not been described and which possessed great merit, namely, the direct percussive electrical rock-drill, modelled upon the lines of the drills driven by steam and air of which examples had been given. There were no doubt a number of ingenious inventors at work upon the subject, particularly in the United States, and he knew at least four machines which were now being experimented with in America, only one of which had been mentioned in the discussion, that of Mr. Van Depoele. So long ago as 1880, his friend, Mr. Charles Ball, of New York, invented a percussive rock-drill, the principle of which he believed was being employed in other drills at the present time. It consisted of two solenoids, in which there was a loose soft-iron bar on a piston as it would be in the steam-drill, caused to vibrate by the action of a current which was made to pass through each solenoid alternately by a tappet arrangement outside the drill, which no doubt would cause sparking, and would be liable to considerable damage under the rough conditions in which the machine had to work. The arrangement would never, he imagined, be successful in that form. But there was a machine called the Marvin electric rock-drill, which seemed to have got over many of the difficulties. The solenoids in that case were operated by alternating pulsations of current directly produced by a dynamo, which had a special attachment upon the commutator. There was no make-and-break contact whatever upon the drill. The solenoids were enclosed in a casing of boiler-tubing, and mounted on a tripod in the ordinary way. That machine up to the present time had managed to achieve the remarkable record of boring 2 inches per minute with a hole 2 inches in diameter, which was not a serious performance for underground work. He was afraid that the principle adopted in the model of the flying insect which had been described, would not be serviceable for such a purpose, and would probably be as much a failure as would be an attempt to make a serious steam-

Mr. Bolton.

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Mr. Bolton. engine work upon the same principle. The blow given by a drill on a hard rock was very heavy in comparison with the size of the instrument. A 3-inch drill, weighing with its tripod at the utmost 300 lbs., might possibly hit a blow of upwards of 900 lbs., taking it in a vertical direction and obtaining the full benefit of the momentum of the piston running at a speed of perhaps five hundred strokes per minute. He knew of no exhaustive experiments to determine the exact force of the blow of a rock-drill. Everything in mining went by the ultimate result, namely, the amount of speed at which they could drive a heading, which in this country was not so great as in the United States. He would only refer to one instance of rapid driving in America as showing what electrical drilling would have to compete with. There was a tunnel being made in hard red granite 8 feet high by 16 feet wide, and two Ingersoll-Sergeant 3-inch rock-drills were used. The heading was driven 98½ feet in one week, as certified by the engineer of the railway. That was a remarkable performance, and, as far as he knew, the most rapid on record. The experience of a number of speakers had been cited in favour of electrical machinery as against the use of compressed air, and he did not hesitate to say that he was to some extent a convert. But all experience did not go in the same way, and there were cases in which electrical machinery had been put in operation in extensive mines and afterwards withdrawn. He might instance that of the Girard Coal Company in Girard, Illinois, where a complete electrical plant had been put in and afterwards pulled out. The circumstances were not actually before him, but he believed they went to show that great consideration was required before a complete plant of electrical machinery was adopted. He ventured to think that with all hard-rock mining the crux of the whole question was the use of a percussive rock-drill. When that was attained, electrical machinery would be largely used in hard mining; but it was of no use whatever to put down electrical plant for the purpose of hoisting, pumping, etc., if at the far end of the adit or heading they were obliged to use compressed air to drive the drills. There was also another point, namely, that at the end of the headings, which were in many cases extremely confined, a supply of air was absolutely necessary. One speaker had mentioned that it would still be necessary to convey air to the extreme end of the heading. That was an undoubted fact, and it would obtain equally with electrical machinery and with rock-drills operated by compressed air. He did not think that the unfortunate air-compressor had altogether had a fair chance in

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the discussion. He thought he might fairly say that quite 99 per cent. of the air-compressors he had seen—and he had seen a great many—had been operated by steam-engines of the crudest and simplest character, and in many cases of very inferior workmanship. One speaker had said that anybody could put an air-compressor together. So they could, but the machines so made were brought forward as showing what compressed air could do, and they were told that no better economy could be got out of them in the end than 26 per cent. With bad engines and with faulty systems of compressing air, with restricted pipes, and with a poor motor at the far end, nothing better could be expected. With electrical machinery, on the other hand, they had the latest systems; the engine was applied to drive the dynamo directly, and they had certainly in the motor a machine of a very high efficiency. But he thought that air-compressors might possibly in future be made of a better type and have better engines supplied to them. He had laid on the table a paper which had reached him only that day from the United States, showing a large compressed-air plant put down with compound condensing Corliss engines of the finest type, and he ventured to think that the results of those engines would be very high indeed. He had also a record of an air-compressor of the direct type, in which the total loss by friction was only 5 per cent. That showed that a good deal might be done in the direction of simplifying the machine. With reference to the percussive electrical drill, he had seen a printed statement to the effect that it would cut about 8 feet per hour in granite, and it required about 5 HP. Those were items which should be borne in mind in comparing its performance with that of other drills. Mr. Bolton.

Prof. HENRY ROBINSON wished to refer to the Authors' statement with regard to the advocacy of a particular system. He thought it was desirable to avoid advocating in that room. They ought as far as possible to confine themselves to facts and not push home their opinions or predilections too far. He agreed with Mr. Bolton in the main in his observations concerning compressed air, but when he stated that an electrical installation had been taken out of a coal mine it was important to know the reason why it had failed. It was impossible to judge without that information, and the bare statement might prejudice a system which was now coming into vogue. The Paper referred to the advocates of compressed air as not having recorded the results of experience in the same way as the Authors had with regard to the system which they were certainly pushing forward with a great deal of advocacy. Professor Robinson.

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Professor Robinson.

It was true that there were no good recent observations concerning compressed air, but in the absence of such data, he thought it was undesirable to bring forward the results of experiments made in 1874. He agreed with Mr. Bolton that many of the compressors in use at that time had become quite obsolete; or, if they were still at work, they ought to be broken up. He had carried out works for compressed air at Birmingham on a somewhat large scale, and some experiments were made last year with a view of ascertaining as nearly as possible the efficiency of the system. There were thirty-four motors worked by compressed air at 45 lbs. above atmospheric pressure, and it was found that the average efficiency of them was 42·66. When he said the average efficiency, he wished it to be understood that the fittings of some of the motors were very imperfect, so that the results were lower on that account. It was only right to say that in some cases the air, besides being used expansively, was heated before utilization, which was, of course, an important feature. In many instances, however, waste heat was employed, so that it did not cost the manufacturer anything. But taking the bad with the good, the average efficiency was 42·66. Within a short time after those observations were made the most defective motors were altered, and the working parts modified so as to give better results; and, as far as he had been able to ascertain, the average efficiency had been raised to 45 per cent. In another case a 40-horse engine, worked by compressed air, was experimented on very carefully, and the air was heated to 280°, and the efficiency in that case was found to be 73 per cent. Those figures might be taken as accurate, and he thought that they should be recorded. When he heard of the average efficiency of compressed air being as low as 20 or 25 per cent., he felt that those who were not familiar with the subject might receive an erroneous impression. For example, in the Birmingham works at the central station installation, in one corner of the site there was a small 200-HP. engine, which was used during the laying of the mains for testing, and in another part there were three triple-expansion high-speed engines of 1,000 HP. each. If diagrams were taken from the old type, no doubt they would show a very low efficiency, but it would not be right to take the average efficiency of the old, badly constructed 200-HP. engine, and the good modern engines as a fair representation of what compressed air would do. Nobody would now put down such an old-fashioned type of compressor. Many of the most important parts had been modified materially, so as to give much better results. It was, therefore, desirable to avoid

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coming to the conclusion arrived at by the Authors, and he thought that the tables they had given were rather hard upon compressed air. He would only say one word upon the other form of energy, in which he was equally interested, for he happened to be carrying out works for the utilization of electrical energy for motive purposes, and was therefore not an advocate of either one or the other. At the present time the St. Pancras Vestry were carrying out a large installation, and next month there would be an exhibition of electrical apparatus in St. Pancras Hall on a large scale, which would probably afford a good deal of information on the subject to those who were desirous of obtaining it. He had had to do with the application of various forms of power for labour-saving appliances underground. He had examined collieries under different conditions, and was quite certain that he would never advise the introduction of a motor on a system which would increase the risks in fiery seams. Any one who had had to do with collieries, and knew the recklessness of the ordinary miner, would hesitate to increase the dangers which already existed. He desired in conclusion to express his great pleasure at seeing the Authors present, and at finding, so soon after the distinguished course they had pursued at King's College, they had made a mark in life. Professor Robinson.

In answer to Mr. Ll. B. Atkinson, Professor Robinson said the 73 per cent. meant the total efficiency from the engine to the motor, including the waste in the motor. Both the brake and the indicated HP. had to be taken into account at the same time.

Mr. T. E. CANDLER remarked that he had been brought up among fiery seams in the north, and had since had a great deal of experience in mines in various parts of the world. He was afraid the discussion had been to a great extent between the advocates of compressed air and of electricity. The Authors had chosen for the application of electricity the most difficult machine, from a miner's point of view, which they could possibly have selected, and he was inclined to agree with Mr. Bainbridge that it was not an effective one for coal-cutting. Mr. Bainbridge had brought forward one which Mr. Candler had seen doing very good work; but it was not desirable that a machine in which sparking occurred should be introduced into a mine where there was gas, whether the sparking would light it or not. Until that point had been definitely settled by experiment, neither Her Majesty's Inspectors of Mines, nor any colliery managers, would be right in allowing it to be used. The method of bottling up the spark was another thing that no mining engineer should agree to, because Mr. Candler.

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Mr. Candler. there would always be a danger of something happening to it. It had been remarked that if the ventilation was not sufficiently good to make the coal mine safe, it should be made so; but the speaker had evidently no idea as to the way in which fire-damp was found in a coal mine. At one moment the workings might be perfectly safe, and at the next, through some atmospheric change, or some big fall in a goaf, large volumes of gas might be sent temporarily into them. That was one reason why the safety-lamp was so useful, because it showed when the danger existed, and they could take steps to drive the fire-damp away as quickly as possible. One great benefit derived from the use of compressed air for driving rock-drills was the assistance which it afforded to the ventilation. It had been largely employed in metalliferous mines, in driving adits or tunnels, where, if electricity had been used, they would have had to adopt some expensive mode of renewing the air. One speaker had quoted some very low figures as to air-compressors. Mr. Candler had been told by the best authorities in the United States that the efficiency was always between 40 and 50 per cent., and that it was impossible to put the average below 40 per cent. for ordinary air-compressing machines. In the north of England he had tested a good many, and during the last six or eight years they always attained from 40 to 43 per cent. The use of electricity in mining would be valuable chiefly where the water or other motive power was a long distance away. In various parts of the world there were minerals of great value, where there was no other power that could be brought to bear to work the machinery required. An illustration had been given by Mr. John Taylor, in which the mine was several hundred feet above where the water-power was. That was a case in which transmission could only be effected by electricity. In some parts of the world he had seen power taken a distance of 2 miles by wire-ropes. He should think the efficiency must have been extremely small. In other places he had seen it conveyed by water through pipes for a very long distance. He was not able to state the exact loss in friction and from the contortions of the main. Another case in which he thought electrical power might be tried, was that of a mine where there were forests a long way off, over inaccessible mountains, and no fuel was to be obtained in the neighbourhood. If the forest could be cut down cheaply plant might be laid down, and the power carried along wires as had been suggested. He had seen electricity used with great effect for pumping in old abandoned mines in order to test them. It was possible to go to places very difficult of access with a

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portable electrical pump and a small quantity of wire. Those were cases in which the Authors might render great assistance to mining operations by the application of electricity; but as far as coal-cutting machinery was concerned, he was afraid that it would not at present, at any rate, be very useful. Mr. Candler.

Mr. Frederick Hurd thought the question of danger had been very much overrated. He spoke from practical experience. It was no uncommon thing for him to spend a sixteen-hours' shift in a mine day after day. He had seen machines at work and giving off sparks that would amaze some persons, in places where they had been most particularly requested to be careful, and he was quite sure that it was not possible for these sparks to cause explosions in the way referred to. In the north of England, in Cardiff, and all over the country such machines were used; also in France, Belgium, Austria, Hungary, America, New Zealand, India and China, in places where large volumes of gas were supposed to be constantly given off. It was impossible for the cutters to come in contact with the grit and pyrites in the coal without giving off some sparks, and there was more danger to be anticipated from the cutter than from the dynamo. It had been stated that electrical machinery for coal-cutting was entirely out of the question. He could only say that there were now scores of collieries which had been working at a loss, and had never paid a dividend until they adopted coal-cutting machinery. He had known instances in which air-compressing plant had been put down, a single machine costing £700 or £800, and after eighteen months' use £7,000 was expended upon an air-compressor. If any one wanted to get information as to what they were doing in the way of cutting coal, the reply would be: "It is an experiment. Try it for yourselves; we have nothing to say." His firm had taken contracts for 1*s.* 6*d.* a ton, finding the machinery, keeping it in order and providing the men, and they had received large royalties. They had often had notice that the mine-owners would be glad to close the contract and purchase the machinery, but they held them to their bargain, and told them, "We have contracted for three years, and if you want the machinery you must buy it," adding three years' royalty and profits. In some cases that had been done. He thought that in the appliance described by the Authors there was more than a germ of success. It had had a remarkable beginning; it was not a mere theory, for it had been put in practice for four years, and it could not be denied that the work had been successfully accomplished. It was the mining engineers who would evidently be benefited by Mr. Hurd.

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Mr. Hurd. it; but at present they did not seem to care to encourage it. They said, "If we give a man a pick and lamp it matters very little whether you see him or not, but if we get your machinery it means three or four nights a week going down to see what is being done." There could be no doubt that electrical plant had its advantages, if only for the handy way in which a small wire could be used to transmit power. Reference had been made to what might be accomplished with compressed air, but even if they could get cent. per cent. the advantages obtained would not compare with the facilities that would be procured by the introduction of wire. The large pipes necessary to convey compressed air were a source of great expense; and they were at the mercy of any one who wished to play them a trick. A man would be very careful before he interfered with a wire, and that was a point in favour of electricity. In a large colliery where 1,400 or 1,500 tons a day were brought up by the use of machines, it would be found that the difference occasioned by the portability of the wire was very great. Formerly there was no way of ventilating except by the old system of bratticing, which was very costly. But in driving a heading by compressed air it was found that all the bratticing was unnecessary, and that the exhaust from the machine ventilated far better and more safely than any other way. It had been said that in cases of that kind compressed air would be needed. He quite admitted it, and it was very proper that Government should step in and compel them to use it; but there was a great difference between employing it for motive power and for ventilation. He ventured to say that with a 2-inch pipe the largest colliery in Great Britain could be ventilated thoroughly, and with a better result than at the present time. Every corner of the mine could be utilized and made safe, and machinery used for hauling, pumping, driving a heading, or cutting coal, in straight work, pillar and stall work, long-wall work, or any work they liked. The weight of the machine had been objected to, and it had been said it was important that it should be portable. If they wanted good work to be done, they must have something heavy behind it. One speaker had complained that the machine shifted about, from the vibration caused by working. If the weight were greater this would be prevented. Many thousands of pounds had been wasted by colliery engineers and managers over light machinery. They had made their machines from 4 cwts. to 1½ ton, and they found that they had greater control over them, and could move them about with as much facility as those of less weight. The

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result was that they had never had any break-downs, the machines always standing to their work. They required no fixing to the sides or the roof. The wheels were all coupled together by connecting-rods, like double bogie-engines. They could easily be moved forward, but would not move backwards when cutting operations were commenced. Mr. Hurd.

Mr. E. R. DOLBY remarked that various speakers had alluded to the danger of sparking in fiery mines, and Mr. Crompton had stated that he thought the risk from the sparks produced by pick-axes was almost as great as that from the sparks on the commutator of a motor. After the disastrous explosion at St. Etienne, in France, a sub-commission was appointed consisting of three well-known gentlemen, Messrs. Mallard, Le Chatelier and Chesneau. They had prepared fire-damp, pure C_2H_4, and let it into a wooden box from a Bunsen burner. In that way they had produced a mixture of different percentages of fire-damp and air. They then placed pieces of sandstone and porphyry near the box, and struck them with pick-axes in such a way as to cause sparks to fall into the box. The mixtures were made so that a naked light ignited them. They found that a mixture of ordinary illuminating gas and air could be ignited by sparks so produced. They then proceeded to experiment upon the fire-damp mixed with air, and they found that it could not in any case be ignited with the sparks. The pick-axes were made of mild steel with removable points, such as were used at St. Etienne, and also of iron such as were employed at the Anzin mines. Besides these they tried picks of steel with 13 per cent. of manganese, and also of aluminium bronze with 2 per cent. of silicon. The aluminium bronze picks produced no sparks, and in the whole series of experiments they never succeeded in igniting any mixture of fire-damp and air. That, he thought, was exceedingly satisfactory. It had been said that the sparks produced on the commutator never caused an explosion, and he thought it was clear from the experiments he had mentioned that sparks from pick-axes would not do so.[1] Mr. Dolby.

Mr. HOWARD D. PEARSALL said it had been confidently asserted in the discussion that the efficiency of electrical transmission was high, and that of transmission by compressed air was low. The cost of the latter had also been asserted to be much greater. Both those statements required considerable modification. With reference to the cost of an electrical installation, he would only Mr. Pearsall.

[1] "Le Génie Civil," vol. xvii., 1889, page 238. Also Minutes of Proceedings Inst. C.E., vol. cii., page 396.

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Mr. Pearsall. remark that the Authors' estimate was based entirely on the asserted high efficiency of the transmission; so that unless that claim was maintained the estimate also fell. With regard to compressed air the Authors' estimate for pipes was only correct for a small plant with low efficiency, and was very much beyond the mark when the efficiency was as high as he should presently speak of. The best result in electrical transmission which had been laid before the Institution was that given by the Authors in Table II, but it could hardly be said to be substantiated by the "precise particulars" which according to the Authors were so amply furnished for electrical transmissions. There was nothing whatever in the Paper to indicate how those figures were arrived at; and from the way in which they were printed side by side with an estimate of air-transmission they also might be merely an estimate, and not the definite results of an actual trial. Still less was it asserted that they were the average of a long continued series of trials; indeed the Authors' own Table I threw doubt upon their Table II. There the ratio between the indicated efficiency at the pumps and the brake HP. of the prime mover was given as 67 per cent. at the highest, and 51 per cent. at the lowest, taking the three efficiencies of the dynamo, cable, and motor. But besides this, 15 per cent. had to be deducted from those figures for the difference between indicated and brake HP. of the prime mover. According to Table I, therefore, the actual efficiency of the plant never exceeded 50 per cent., and was sometimes only 36 per cent. That was for a transmission of 2 miles; at 4 miles, 32 per cent. would, according to the same table, be the maximum. This efficiency was that of the generating and transmission plant alone, without taking into account the further loss in the pumping machinery. Similarly, another statement, which was made with great emphasis by Mr. Taylor, did not, after all, show such a high result when certain other items were taken into account. Mr. Taylor had given them information only with regard to the efficiency of transmission, which he stated was 85 per cent. But that was not the efficiency of the plant, but solely that of the conductor, and meant that 15 per cent. of the power was lost in only 2 miles of cable. The loss in transmission in Paris by compressed air through 3 miles of pipe was stated, on the authority of an independent report of Professor Kennedy, to be only 2 per cent. With a loss of 15 per cent. in the cables, the total efficiency of the plant described by Mr. Taylor could not have been more than 45 per cent., and in all probability did not average 35 per cent. of the gross power of the waterfall. Besides that he believed nothing had been said about

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Mr. Pearsall.

the great falling off of efficiency, which was known to occur whenever the dynamo ran at any other than its best speed. The unsuitability of the plant for driving some kinds of machinery had been strikingly shown by the Authors' figures for pumping by electricity, where they indicated, in one case, a net efficiency of only 10 per cent. He thought it was no exaggeration to say that the worst results with compressed air could be paralleled by similar ones with electricity. But in designing pumping plant an engineer would not assume a consumption of 10 lbs. of coal per horse-power per hour, merely because there were bad engines in existence which required that quantity. He maintained that it was just as unreasonable to assume an efficiency of 25 per cent. or 30 per cent. in contemplating an installation for distribution of power because there were faultily designed plants which gave no more than that. The Paris installation was most carefully tested by Professor Kennedy, who found an efficiency of 40 per cent., but at the same time expressly stated that the arrangements were palpably imperfect. The greatest fault was that the air was not properly cooled during compression, and the loss from that cause alone was nearly 40 per cent. Actual experience had proved again and again that sufficient cooling could be applied to the cylinder to reduce that loss to at most 25 per cent. Making this correction, the efficiency of the Paris installation would be 50 per cent., and that was the least that any competent engineer should expect to get at present. But in many places the original motive agent used was water-power. In such cases 50 per cent. was by no means the limit of what could certainly be done. There were two reasons for this, the extreme simplicity of the machinery and the fact that they had a practically unlimited cooling agent at their disposal, and that by properly applying it almost the whole of the 40 per cent. loss, which occurred when the air was not cooled, was avoided. The machinery he referred to was that in which the air was compressed directly by the water. In air-compressors driven by steam-engines it was usual to employ a quantity of water for cooling equal to about two-thirds of the weight of the air compressed, but in the machines to which he referred he had succeeded in using for cooling a quantity of water a thousand times the weight of the air, and moreover, it was employed in the most efficient manner, the cooling surface being distributed throughout the air to any desired extent. He had compressed air in that way without being able to detect any rise of temperature at all. In the Paris installation the efficiency of the prime mover was 84·5 per cent., and that of the compression was 61 per cent. The product of these was

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Mr. Pearsall. 51·5 per cent., and the actual net efficiency of the whole plant was that ratio multiplied by the efficiency of transmission and that of the secondary motors. In compressing air by water-power on the principle to which he referred he had obtained an efficiency of 85 per cent., and if that was multiplied as before by the efficiency of transmission and of the secondary motors, the net efficiency to be realized at a distance of 3 miles was 67 per cent. On consideration of facts which were already well known, it would be seen that this result was in fact only what was to be expected. Those facts were (1) That 40 per cent. efficiency could be and was attained even with no cooling, as in Paris; (2) That the absence of cooling caused a loss of 40 per cent. of the gross power; (3) That a quantity of cold water, a thousand times the weight of the air, could be used so as to produce a nearly perfect cooling. Hence 40 per cent. waste was saved. If they could eliminate, in the case of the Paris installation, the loss from the heating of the air, all the other losses would amount to only 33·33 per cent., leaving 66·66 per cent. net efficiency. He had succeeded in eliminating that loss almost entirely when the motive agent was water-power, used in the way he had indicated; hence they might expect an efficiency of at least 66 per cent. in such a system, without taking into account what was due to the greater simplicity of the machinery. Even that was not the limit of what was possible. Directly the difficulty from heating was removed, they could use much higher pressures, and so obtain a great economy in the mains. The efficiency of the secondary motors could also be largely increased by making due use of the special facilities which the system he had perfected gave. He would not go into details, as it was too large a subject. It was sufficient to say that the principle had been actually carried out, and was no longer only a theory. Compression of air, with an efficiency of 85 per cent., was an accomplished fact which could be seen any day, and he thought it could not be denied that what he had ventured to call the natural and necessary consequence of that fact was a net efficiency of transmission, at any distance, superior to that attainable by any other known method.

Mr. Trotter. Mr. A. P. Trotter remarked that his only excuse for speaking was that the first two of the machines in question were among the last which he had made before withdrawing from his manufacturing business, and he was pleased to see that the principle on which the Authors started—that of the rotary cutter geared to the motor—had been adhered to. The development of the invention had consisted in the elaboration of the details, and if the Authors had tried first one coal-cutter and then another, they would

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Mr. Trotter.

probably not have achieved the results they had already accomplished. Many arguments had been put forward against the use of the machines in coal mines, but the only experiments which had been adduced (besides those that had just been mentioned, and which were not electrical) were those of Mr. Snell, and he did not succeed in igniting a mixture of coal-gas and air by means of sparks from a machine, until the commutator got seriously hot. With the large armatures used in the motors for the purpose of keeping them cool, it was obvious that the temperature of the commutators need never be allowed to rise to such an extent. Mr. Snell had mentioned carbon brushes. Mr. Trotter would have been glad to have more information about them, because his experience was that they heated more than any other form of brush that had been tried. But where the only reason for the ignition of a mixture of air and gas was the fact that the commutator got hot, it seemed that carbon brushes would not be suitable. Those who had spoken of fire-damp igniting at the machine appeared to have lost sight of the fact that with the carefully-protected cases used in the motors, the fire-damp could not suddenly produce an explosive mixture. It must leak in by degrees, and, as the Authors had stated—though this had evidently escaped the attention of Professor Forbes and others—before it could become an explosive mixture, the gas would burn, if it could be ignited at all by the spark, in the same way as in a miner's lamp. When the fire-damp got into the lamp it did not suddenly become an explosive mixture; it gave warning, and when the miners retired, they need not let the coal-cutting machine continue to run; the current might be cut off at the spot, or when they came back to the main switch. It was rather disappointing that the discussion which directly challenged air-compressing engineers, had not brought out a few more figures. He had hoped that at Birmingham they had attained something better than 44 per cent. It was difficult to know, with regard to the Paris installation, how to distinguish between what they were doing and what they might do. At all events, the 44 per cent. or even 50 per cent., was an enormous encouragement to electrical engineers, for there were few cases in which they need go as low as that. The loss by transmission in cables might be put at 10 per cent. or 20 per cent., leaving an ample margin for losses in dynamos and motors. Evidently air must do a great deal more than it had yet done if it was to compete with transmission by electricity in mines or elsewhere. It was remarkable that the only speaker who had really upheld the Paper, was connected with air-compressing

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Mr. Trotter. machinery himself, and knew the difficulties of both systems. One interesting feature of the Paper was the application of electricity to mechanical engineering. They had all seen what terrible blunders had been made in tramway work by persons who knew something of motors and very little of tramways. The inventors of these machines had, after learning electrical engineering, studied the details of the art of coal-cutting, and adapted their motors to it. The only criticisms that had been made from a mechanical point of view, had been upon the Ingersoll drill. Not a single word had been said as to the electrical driving. It had been stated in the discussion that the wheel-cutting machine was better than the bar-cutter; but the amount bared with the bar-cutter was, if anything, rather more than with the wheel. He believed that the first machine, which used to tear both itself and the coal-face to pieces, and to throw itself off the rails, and hang on by the cutter-bar, travelled at the rate of about a yard a minute. The Authors had not mentioned one rather important point, namely, how many men would be required to do the same amount of work as one of the cutter-bars. The Authors had stated that they were going to try a reciprocating machine. That was one of the most difficult problems that an electrical engineer could have to deal with. To produce anything on the reciprocating principle larger than the electric bell, and make it work with fair economy, seemed exceedingly difficult.

Mr. Ravenshaw. Mr. H. W. RAVENSHAW observed that series-wound motors were always used for high voltage because they required comparatively few turns on the magnets, whereas shunt-windings for high voltage required a large number of turns, and there was a great liability to failure of the insulation if the shunt-circuit was broken. The only difficulty with a series-wound motor was, that when working on a constant-potential circuit, if the load was taken off the machine was liable to run away at a very high speed. He had been working on the subject for some time, and had found that by using iron or steel having a great amount of hysteresis, *i.e.* retaining the magnetism induced in it, he could make a motor which would not race. Employing Dr. Hopkinson's curve for hard mild steel, he came to the conclusion that, in the case of a machine he was building, which was intended to run at 600 revolutions, if he used soft iron magnets it would make on open circuit about 2,400 revolutions per minute, which would mean the destruction of something in connection with it. With mild-steel magnets, the maximum speed would be only 1,800 revolutions, a reduction of 25 per cent. But, by employing an automatic

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switch so arranged that when working at full load the two halves of the magnets would be connected in parallel circuit, and when below half load they would be connected in series, he found that with steel magnets the maximum difference would be from 600 revolutions at full load to 780 revolutions with light load. That would be an allowable variation in any case where great regularity was not required, and between full-load and quarter-load the speed would not exceed 680 revolutions per minute. Mr. Ravenshaw.

Mr. C. W. Atkinson in reply, said that several speakers had referred to the question of the relative merits of cutter-bars and cutter-disks. Their remarks, he thought, had chiefly arisen from a misconception of the method of working the particular cutter-bar referred to in the Paper. Mr. Bainbridge had drawn attention to the fact that in the disk machine the cutter was made to revolve outwards and split the coal off along the line of least resistance, and consequently nearly the whole baring was done by splitting and not by cutting. When the Authors began coal-cutting they used the Blackburn cutter-bar (Fig. 18), with which it was intended to cut the whole of the coal. The cutters on the stars were arranged one after the other so as to bare the whole surface. They soon came to the conclusion that it was a wrong method, and that it was better to imitate as far as possible the action of the common miner's pick, and that was what they had endeavoured to do in the cutter-bars they had designed. Instead of placing six cutters on one star-shaped holder, they now placed them one after another so as to form a single-threaded screw with a pitch of 1 inch. The consequence was that each one cut a narrow groove about $\frac{1}{8}$ inch in depth, and the edge split the coal off into the next, so that nearly the whole baring was done by splitting and not by cutting. The result had been to reduce the power required by at least one-half, and to produce much less fine dust, and in every way to improve the nature of the cutting. Other questions involved the nature of the particular situation. Disk-cutters might be employed where the roof was very strong, and where there was little danger from jamming, but in most cases there was this risk, and consequently the bar-cutter was more generally useful. He thought that the greater part of the criticisms had arisen from a misunderstanding of the nature of the bar. Several speakers had stated that the wear and tear of the compressed-air machines was much less than that of electric motors. He did not think that was the case. The whole machine shown in the diagrams was completely enclosed in dirt-tight cases, the gearing itself running in oil, the only revolving part visible Mr. C. W. Atkinson.

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Mr. C. W. Atkinson. being the cutter-bar, and that formed a dirt-tight joint at the gear-box cover, so that after many months' running, when the lid was taken off, the oil was perfectly clean. The consequence was that whereas in air-machinery they considered it a fairly good record if a pair of brasses wore two or three months, the wear of the brasses in the electric machines was so small that after some months it was hardly perceptible. He thought, therefore, that the mechanical wear was less in the electrical than in the compressed-air coal-cutting machine. In reference to electrical wear they had never found any difficulty. The armatures were very strongly constructed, the repair required was only on the commutator, and in their experience that had been extremely small. Several machines had been running for years without requiring anything more than an occasional turning up of the commutator.

Mr. Ll. B. Atkinson. Mr. Ll. B. Atkinson said that exception had been taken to the Authors having used the results of figures published originally in 1874; but it would appear from the remarks of Professor Lupton, that the only improvement he was able to record since that date was one of 25 per cent., and he appeared to have fallen into the error of believing that he could add this to the 31 per cent. efficiency, making it up to 56 per cent. It was, however, only 25 per cent. of 31, or about 6 per cent. more. Professor Robinson had referred to the experiments at Birmingham, but he did not say whether he took the brake HP. of the generating-engine and of the motor, or whether he took the indicated HP. The Authors had been careful to state that they took the brake HP. of the engine and of the motor, and he hoped that Professor Robinson would make it equally clear what figures he had relied upon. It had been stated that the Paris figures might be very much improved. Possibly they might; all that the Authors had ventured to do was to deal with the figures which had been actually obtained, in working with electricity and with compressed air. They had given the figures obtained from working tests of the motors; the only remaining element being the loss in the cable, and that, in the present stage of electrical science, was a mere matter of arithmetic, and not a question involving any theory. Another important point upon which special stress had been laid was the question of the safety of electricity in fiery coal mines. Professor Lupton and Professor Forbes had contested the Authors' statement, that the arrangement of covers designed by them afforded a safe means of employing electricity in mines. The Authors had stated that all experiments went to show that

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there was very little danger of ignition, but that if there was any the proposed arrangements obviated it. Professor Forbes said that the casings looked very nice in the drawings, but as a matter of fact would not exclude the gases. Mr. Brain thought if they could prove their case and keep the gas out for two hours mining engineers would be satisfied. In order to settle that point they had one of the boxed-up motors placed inside a large box filled with coal-gas, or coal-gas and air. After five hours they drew out, by means of a pipe, some of the gas inside the cover surrounding the armature. This was passed through the eudiometer, and they endeavoured to explode it with an electrical spark, but were unable to do so either when it was mixed with equal volumes of air, or with four volumes of air, or taken as it was from the interior. As a check they ascertained by experiment that they could explode a mixture as weak as 1 in 14. For the purpose of measuring the actual proportion of gas inside the covers, Mr. Pitkin had kindly lent them one of his gas-detectors, which were very sensitive. The result showed that after five hours, in an atmosphere with very much more gas than would be found in any coal mine in existence, only 0·5 per cent. of gas could be detected in the chamber. He thought that that answered both Professor Forbes' theoretical objection and also the remark of Mr. Brain. He might mention that the motor was stationary, but that was rather a disadvantage, as it was found that the chief leakage was through the bearings. When the motor was running the oil was evenly distributed on the bearings, and there was no tendency to leakage. Professor Forbes had dwelt at great length on the danger of using motors, and afterwards called their attention to the Tesla motor. They had heard of that machine for two or three years, and it had always been going to take them by storm, and do many wonderful things. The last time he made inquiries about it, nearly a year ago, he found that it was still unpurchasable even from the manufacturers in America. He thought therefore that they ought not to wait until the motors had been perfected before attempting to do mining by electricity. Professor Forbes had admitted that there was a difficulty about starting the Tesla motor, and if so that would be a fatal objection to the employment of it for coal-cutting. Sometimes, after a stoppage or a fall of the roof, the cutter-bar became jammed so tightly that a man might pull as hard as he could on a long lever placed between the bolts of the coupling and not be able to move it. By suddenly switching on a current to a motor that would take 25 amperes, with an engine with a heavy fly-wheel, they

Mr. Ll. B. Atkinson

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Mr. Ll. B. Atkinson.

might get 100 or 150 amperes for a second or two, and that would pull the motor clear almost of any stoppage. The Tesla motor was difficult to get to start at all, and could not possibly move the machine in a case of that kind. The great advantage of electricity in coal-cutting was the enormous power of starting where there was a block. It was surprising to see how a machine weighing 1½ ton would lift itself up off the rails at starting if the cutter was jammed. The rock-drill shown in Figs. 8, Plate 4, was one which the Authors had actually worked, and the difficulties connected with it were not electrical, but mechanical. The drill was not strong enough to stand the continuous wear brought upon it, and some of the cams and rods gave out. In reply to the question as to what work it had done, he had been informed that it had driven six holes, each a yard deep, in three and a half hours. That was not a great performance, but it was more than they had been doing by hand in the headings where the drill was put to work. A good deal had been said about direct-acting percussive rock-drills, and in the Paper the Authors had indicated that they were at present working upon such a drill, which they had every reason to believe would yield results better than those given. They had, however, confined themselves to what they had actually done, and had said nothing as to the results anticipated in the future. With reference to the question of the relative merits of the bar-cutter and the disk-cutter, two or three speakers had stated that they believed the latter would do the most work, but unfortunately they had given no data and no reason for the supposition. He knew that the makers of disk-cutters were very particular to choose soft materials to work in, and would not try them in hard. The Authors, on the other hand, had considered that they ought to cut in what the manager of the pit thought was stuff that he could best afford to waste, and the cutters they had designed were used in material which disk-cutters would probably not work in at all. He believed that Mr. Frederick Hurd, who had had a great deal more experience than any one present of disk-cutters, looked favourably on the form of cutter given in the Paper, after having considered the relative merits of both. Professor Lupton's argument that they ought not to attempt to use electricity in coal mines, because there was a remote possibility of an explosion, might be applied to almost every class of machinery. There were boiler explosions and railway collisions, and cables were occasionally over-wound with serious results; still they did not say that those mechanical contrivances ought not to be used because accidents might possibly

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happen. The proper way of approaching the subject was to inquire if the thing was worth doing. Professor Lupton said that it was, if the Tables of efficiencies given in the Paper were correct, and he did not seriously confute them; Mr. Atkinson therefore concluded that it was worth attempting, and the Paper was the record of what they had done in that direction. Reference had been made to the firing of gas by sparks from a pick-axe or from any steel instruments striking against a hard material. Mr. Atkinson had recently read in the *Colliery Guardian* a report of the Prussian Fire-Damp Commission, in which he found the following paragraph:—"Doubts have often been raised against the supposed harmlessness of lighting by means of a spark from steel (flint and steel), because according to the experiments of Messrs. Vilaine and Griot, the sparks thus obtained inflame the lighting gas, and also because it appeared as if the steel mill of ancient use, both in England and in Belgium, had occasioned explosions of fire-damp. At first, the Prussian Commission decided to investigate this question, but afterwards renounced it on account of the experiments of Messrs. Wüllner and Lehmann at Aix-la-Chapelle, on the inflammability of mixtures of fire-damp by incandescent metallic wires and electric sparks, which proved that even violent sparks from rupture of the current accompanied with the explosion of fragments of iron in a state of combustion, had no effect on the inflammation of fire-damp."[1] The results therefore of experiments so far had been to prove that the danger had been very much over-rated, whilst the system adopted by the Authors practically excluded the gas from the point of danger. Mr. Ll. B. Atkinson.

In further reply to the discussion, the Authors intimated that they would confine themselves, as far as possible, to the ground covered by the Paper, and more particularly to maintain the various propositions contained in the summary, under the headings of A, B, and C, and to deal with the criticisms of the particular arrangements and apparatus exhibited and described. A considerable amount of additional matter had been contributed, but with this they did not propose to deal. The Authors' reply.

The view put forward by the Authors had been supported by Mr. Snell, that under normal conditions, a motor would be unlikely to ignite gas; but admitted also the advantage of arranging it, so that even under abnormal conditions no danger would arise. Mr. Snell had also upheld the opinion of the Authors, that the

[1] *Colliery Guardian*, Feb. 20, 1891

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The Authors' reply.

whole armature ought to be protected, and not the commutator only. His remarks agreed with their own views as to the greatly increased efficiency obtained by utilizing electricity instead of compressed air for pumping, hauling, &c.

In the course of his remarks, Professor Lupton had severely criticised the use of electricity in mines where gas was present, on the ground that, unless certain precautions were taken, danger was to be anticipated, and therefore advised the use of compressed air, unless it could be shown that electricity offered great advantages; but Professor Lupton would lead his hearers to suppose that this advantage did not exist, and that, as the figures given by the Authors in some cases related to machinery made and tested a good many years ago, they were no longer to be relied upon, owing to the great improvements which had been made since. Professor Lupton had suggested further, that there should be a competition between electrical and compressed-air plants transmitting 10 HP. to a distance of 10,000 yards. Table V, which the Authors had calculated, showed what

TABLE V.

COMPRESSED AIR *v.* ELECTRICITY.

Transmission = 10,000 yards.

—	Size Pipes.	Engine B.HP.	HP. given by Generator.	HP. lost in Main.	HP. put into Motor.	Motor B.HP.	B.HP. Motor B.HP. Engine	Cost Complete and Erected.
	Inches.							£.
Air . .	3	62·1	38	19	19	10	0·16	2,500
	4	39	23·6	4·6	19	10	0·26	3,100
	5 & 4	35·8	21·8	2·8	19	10	0·28	3,445
Electricity	$\frac{18}{17}$	19·2	16	4·6	11·4	10	0·52	1,580

results might be anticipated from such a trial, taking Professor Kennedy's experiments in Paris, and well authenticated trials of dynamos and motors as the basis of the calculations. He omitted to give any tables or details of trials, to prove his contention, and in the absence of these data, and in the face of the fact, that all existing records supported the Authors' figures, Professor Lupton's suggestion ought not to be entertained. In criticising Table II, Professor Lupton referred to an installation running at the Trafalgar Collieries, in which the distance was the same, and although a cable of nineteen wires was used instead of seven, as described

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The Authors' reply.

in Table II, there was a loss of 20 per cent., whereas in the Table, a loss of 10 per cent. only was shown. Professor Lupton pointed out that the voltage used at the Trafalgar Collieries was one-half of that proposed to be used by the Authors, and this statement accounted for the whole difference, for by doubling the volts, and keeping the size of the conductor unaltered, the loss would be reduced to one quarter, so that the cable might be halved in size, and the loss still be one-half of that with the lower volts. This corresponded with the Table in every respect. Professor Lupton stated that a 3-inch pipe would be ample for a 10 HP. engine working with compressed air; but every maker of compressed-air machinery to whom the Authors had mentioned the point, had selected a 4-inch pipe for the work, when working at an ordinary pressure of about 50 lbs. to the square inch. Professor Lupton's alterations, therefore, to the figures and prices were incorrect. He also asked what was the price of the machine, compared with that of a compressed-air engine; these costs were given in Table II, the price of both electric and compressed-air machinery being taken at an average market price. Professor Lupton's remarks as to the apparently contradictory advice given by persons whom he had consulted as to the proper voltage to use in transmitting power were capable of an easy explanation. Small motors of ½ HP. to 1 HP. were difficult to wind for more than 150 volts; if, therefore, it was desired to run them from mains supplying large motors, at say, 300 to 500 volts, it was better to work either two or three of them in series, or to insert resistance, and although by this means the efficiency might be reduced by 50 per cent., yet the useful work obtained was greater than would be got from a compressed-air motor of the same size, and to which power was being transmitted for an equal distance. The question as to the best voltage to use was one which an engineer in laying out a plant would carefully consider, in order to get the best results; but criticisms concerning the efficiency of motors as small as ½ HP. running off transmission systems, involving, perhaps, 200 or 300 HP., were not very vital to the question.

Some interesting data relating to electricity in mines had been given by Mr. A. Grothe, but his remarks were rather supplementary to the Paper than in discussion of the points raised in it.

The Authors pointed out that the remarks of Mr. Bainbridge, who, whilst admitting the economy in power gained by using electricity instead of compressed air, stated that, nevertheless, he

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The Authors' reply.

would prefer to employ the latter, owing to the smaller chance of stoppage or breakdown, were unsupported by results. As a matter of fact, the following statement might be given: A dynamo, driving the Authors' coal-cutting machines, was used regularly for a period of two years without any repairs or breakdown. In the earlier coal-cutting machines made by the Authors' firm, some difficulties were encountered with the failure of the armature insulation, but these had been overcome, and there was every reason to suppose that the later machines would last as long as their other motors, some of which had run daily for two and three years, without any breakdown whatever. As to the wear and tear of the coal-cutting machines themselves, whereas the brasses of compressed-air coal-cutting machines lasted usually less than one month, one of the Authors' machines, removed from a pit where it had been working for several months, was examined, and it was impossible to detect any shake in the bearings. This result was obtained by the use of simple rotary motors, and by the entire enclosing in dust-tight cases of every bearing.

Mr. Bainbridge, in describing a pump which he was putting down, had entirely corroborated the statement by the Authors, that the cost of electric plant was one-half that of compressed-air plant. Mr. Brain had quoted the opinion of Mr. Colquhoun, that in his experience the efficiency of compressed-air plant never exceeded 25 per cent., and further, gave the results of some tests of plants of modern construction which showed that 17 or 18 per cent. was all that was obtained in practice, thus showing that the Authors had erred on the side of moderation in dealing with the efficiency of compressed-air plant.

The Authors regretted that considerable bias in favour of a particular system, and apparently want of practical experience of any other, had led Professor Forbes to condemn the arrangements described by them in unmeasured terms. He appeared to be under the impression that most coal mines were normally filled with an explosive mixture, and that the working face was the most dangerous place in the mine, whilst, as a matter of fact, it was generally a part where the air was purer and more free from gas, owing to the thorough ventilation, than in almost any other. It was perfectly true that, if the Authors' motors were left for, say, a week, in an explosive mixture, it would be possible to imagine an explosion occurring from their use; at the same time, such a condition was not in any way likely to occur, and the supposition of the Authors, that an electric motor would not be worked continuously in such a mixture for a longer period than

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two or three hours, was one that allowed an ample margin for every practical case. In reply to the suggestion of Professor Forbes that the words used in the Paper were intended to produce the impression that this machinery had been employed in fiery mines, although such had not been the case, the Authors might point to a pumping-plant, working with one of these enclosed motors, which had been in use in the Murton Colliery of the South Hetton Coal Company for seven or eight months, and which had been approved both by the mining inspectors and by the engineers of the colliery, and which had led to no fires or explosions. Professor Forbes had pointed out the danger of using electric cables at all; but the experience of all colliery owners and managers who had tried them had shown that, if they were properly put down in the first instance, and had reasonable supervision, difficulties of the kind suggested did not occur in practice. With regard to the "Tesla" motor—although machines of this class undoubtedly had a future before them, the Authors thought that no engineer practically acquainted with the requirements of coal-cutting machinery would recommend a motor where, with the latest improvements, the torque exerted at a standstill is considerably less than when running; and although in that motor no commutator is used, nevertheless it would be equally desirable to enclose the armatures, to prevent sparking in the event of a wire being broken. The Authors' reply.

It had been pointed out by Mr. Crompton, in the course of his remarks, which were eminently valuable, as being founded on a wide practical experience, that the Authors had, in referring to the relative efficiencies of electricity and compressed-air plants, erred on the side of moderation; and he had further referred, in answer to Mr. Bainbridge, to the fact of the decreased cost of repairs in electrical transmission.

In reply to Mr. A. Sopwith's criticisms, relating mainly to the question of the possibility of maintaining a roof along a roadway on which the coal-cutting machinery was to be worked, the Authors would point out that the fact of using machinery was in itself the best means of providing a suitable roof, for when the cutting was done by hand, the progress was so slow that the roof was weighted on the roadway, whereas, when using machinery, where the coal could be cleared within a few hours of the starting of the cutting, this weighting on the face was avoided, and much less timbering was required. The contention of the Authors as to the excessive and over-rated apprehensions which existed as to the ignition of explosive gases by electric motors had been borne

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The Authors' reply.

out by the practical experiments referred to by Mr. Sydney Walker; but although Mr. Walker, in this respect, was not an alarmist, he appeared to be one on the question of volts and of shocks. The Authors' system of enclosed motors, in which every electrical part was encased in a metal cover connected with the earth, precluded all possibility of receiving a shock whilst working in the ordinary way, and therefore the dangers anticipated by Mr. Walker were overcome; and although low voltage might, in some respects, be desirable in plants transmitting, say, 100 HP., the currents to be handled became so large, that very great difficulties arose, quite apart from the extra cost of the cable.

The remarks of Professor H. Robinson called for attention, he being the only speaker who endeavoured to support the contention that compressed air was as efficient, or more efficient than electricity, by any show of figures. But the Authors could only assume that the results given as *efficiency* represented the ratio between the indicated HP. of the engine and the indicated HP. of the motor, in which case, as bearing on the present discussion, they were not comparable with those in the Paper. But if the results given by Professor Robinson could be maintained by publication of figures or records, this should certainly be done, as they were considerably in advance of what the Authors had seen.

In reply to Mr. Pearsall's criticisms, the figures in Table II were estimated or calculated, and were placed side by side for the purpose of comparison. The data on which these figures were calculated were as follows:—In the electric transmission, the loss in the cables was accurately known, while the efficiency of the electric motor had been determined by careful experiments to be 85 per cent. The brake HP. of the steam-engine was also arrived at by a knowledge of the efficiency of the dynamo, gained by careful experiments. In the case of compressed air, the efficiencies of the compressing plant and of the air motor were taken from the figures in Professor Kennedy's Paper before the British Association, on the "Popp" system in Paris, the prices in each case being those given by leading makers. The pump in Table II, which Mr. Pearsall criticised as giving a gross efficiency of only 10 per cent., was a small dip-pump, where the quantity of water, compared to the head, was large, and where, owing to the circumstances of the case, the pump was worked from a dynamo of low voltage. In order to meet this point, data were now added relating to another pumping plant (see Table VI), in which every detail, from the indicated diagrams downward, was given, showing a gross efficiency from the indicated power to the water

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delivered of 49 per cent., or, taking the same data as thus used in the Paper, viz., $\frac{\text{HP. in water delivered}}{\text{B. HP. on dynamo}}$, an efficiency of 72 per cent. Mr. Pearsall gave a considerable number of figures, and ended by saying that compressed air, with an efficiency of 85 per cent., was an accomplished fact, which could be seen any day; the Authors only regretted that he did not indicate where it could be seen, as they were quite sure that a large number of engineers would be interested in a result which was certainly unique. The Authors' reply.

TABLE VI.

ELECTRIC TRANSMISSION OF POWER. TESTS OF PUMPING PLANT.

		Per Cent. of I.HP.
Size of cable	$\frac{19}{128}$ S.W.G.	
Distance engine-pump	1,200 yards	
I.HP. of engine	31·75	
Loss in engine and belt	10 HP.	31·5
„ dynamo	1·92 HP.	6·05
E.HP. of dynamo	19·8	62·5
Loss in cable	1·7 HP.	5·36
HP. put into motor	18·1	57·14
Loss in motor	1·5 HP.	4·72
B.HP. of motor	16·6	52·4
Loss in pump and gear	1 HP.	3·15
HP. delivered by pump	15·6	49·2
Gallons per minute	118	
Pressure at pump, lbs. per square inch	190	
Efficiency of transmission—		
or $\frac{\text{B.HP. of motor}}{\text{B.HP of engine}} = \frac{16·6}{21·72}$	..	76·5
Volts at dynamo	410	

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Correspondence.

Mr. Fowler. Mr. GEORGE FOWLER said the Authors assumed somewhat prematurely that in the application of electricity to mining machinery they had to compete only with compressed air. It was perfectly true that of late years the use of compressed air to drive underground machinery had been allowed to occupy the field. In his opinion, steam conducted in pipes, or rope-driven gearing, would have effected the main haulages of many collieries, at far less initial and working cost. Probably no responsible mining engineer would at the present moment introduce a steam-boiler to underground workings. But the loss of power in a range of well-covered steam-piping, 300, 400 or 500 yards in length, would be immaterial in comparison with what it would be in the case of compressed air. And it might be remarked that the exhaust steam of an engine was harmless in most upcast pits. But he desired more especially to speak on the subject of high-speed endless ropes. It must be premised that the main haulages, over which by far the largest amount of power was expended, usually conveyed to the drawing shafts, and the drums or endless-rope gearing which actuated them were, in most cases, located at these points. Probably four-fifths of the haulage power required in a colliery was thus effectively expended within 500 yards of the pit bottom. He thought that this power could be most cheaply conveyed from engines on the surface to the gearing in the pit by high-speed endless ropes. Practically the belt, which in the Authors' arrangement drove the dynamo, was extended down the pit, and taken to the hauling gear where the power was utilized. The extra friction thus introduced was merely trifling, so that instead of the five losses of power arising from the use of the dynamo and motor, namely, (1) friction of the belt on the dynamo; (2) loss of power in the dynamo; (3) resistance of the cable; (4) loss in the motor; (5) friction of the belt or gearing on the motor; there was only the friction of the rope or belt round the four or five large sheaves which conducted it from the engine at the top to the machinery at the pit bottom. He had had considerable experience in this direction, and believed that in one case an effective power of 40 HP. was transmitted to the bottom of a deep pit, with the loss of not more than 10 per cent., and at a cost for ropes not exceeding £10 per annum. He was of opinion that neither compressed-air nor electrical machinery could

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in first cost or working cost compete with this method when the distances from the bottom of the shaft were moderate. With regard, however, to the conveyance of power on long and circuitous routes, for small auxiliary haulages, and for coal-getting machinery, he believed that the Paper contained matter of the greatest value to the mining engineer. The form of coal-cutting machine which the Authors suggested appeared to have great promise of efficiency, although there was reason to fear that in some cases the cutter-bar might get blocked. And the irregular way in which coal seams occasionally broke off at the face, would always occasion loss with a machine which was obliged to take a straight course along a bank face. It was better to employ currents of low tension so as to avoid danger to the men. He was not quite clear whether the Authors used a double cable or returned the current on the rails. The latter course was open to the objection that they might be inadvertently touched. It was undesirable to afford the workmen any excuse for objecting to give the coal-cutting machines a fair trial. Mr. Fowler.

Mr. Herbert W. Hughes remarked that the Authors were to be congratulated on their Paper, which could not fail to be interesting to mining men, and at the same time would remove some of the prejudices which existed in their minds against electricity. The prominent feature of the Paper was the descriptions of apparatus intended to enable electric motors to be worked in situations where an explosive atmosphere might exist. He thought that the results obtained by the Authors were very satisfactory, and would increase confidence. At the same time, it had always appeared to him that the danger of using electricity in mining had been exaggerated. In the first place, the great majority of mines did not regularly contain explosive atmospheres, and in the event of a sudden outburst of gas the motor might be immediately stopped. Sparking at known points, or in the case of short-circuiting, appeared to be preventable, as it depended on the design of the machine, the intelligence of the workmen operating it, and last, but not least, the common sense of the purchaser. In the desire to secure economy in outlay, less money was often spent on safe-guards than should be the case. Electricity appeared to be particularly applicable to the operation of coal-cutting. Machines could undoubtedly undercut coal cheaper than manual labour, under suitable circumstances; but the difficulty of driving them by compressed air or wire-ropes was so great as to nullify the advantages, even where favourable conditions existed. In the facility with which power could be carried about when Mr. Hughes.

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Mr. Hughes. electricity was employed, this medium stood unrivalled, and the cost of up-keep was less than with either of the other systems. Experience in this country seemed to have been confined to the type of machine described by the Authors, but in America several designs had been successfully applied and had been in daily operation for over eighteen months. The machine most in favour appeared to be the one made by the Jeffrey Manufacturing Company. It was furnished with a cutter-bar similar to that described by the Authors, except that the teeth were mounted on a shaft which had the same diameter throughout its length; this shaft was driven by chain-gearing, and was from 39 to 42 inches in length. An essential difference, however, was the direction in which the cut was made. In the Blackburn machine, the bar was at right angles to the face of coal, and the cut proceeded in that direction. In the Jeffrey machine, the bar was parallel to the face and the cut also; it really did the work in the same direction as a miner. When the cut was made to the required depth, usually about 5 feet, the bar was thrown out of gear and withdrawn, the machine moved sideways along the face over the length of cutter-bar, and the process repeated. This system got over two disadvantages: first, the inability of most coal-cutters to work in stalls which were set with timber at close intervals; because, so long as the props were wide enough apart for the machine to be got between (about 3 feet 6 inches), it could easily be placed in position, even if they were close to the face. Secondly, the irregular holeing generally produced when the floor of the seam was undulating; because this machine could follow any variation in the floor which took place within the length of the cutter-bar. From a Paper by Mr. H. C. Spaulding,[1] it appeared that twenty-three of these machines driven by electricity had been applied, and that the amount of work done by each averaged from 600 to 900 square feet of undercut in ten hours. The height of undercut was 4 inches. The distance from the power-house to the working places in the mines varied from 1,000 to upwards of 5,000 feet. The motors were wound in series for 220 volts, with a capacity of 15 HP.

Mr. Rooper. Mr. W. O. ROOPER said that the Tables and data contained in the Paper would prove of much practical value to all who were engaged in the application of electricity to mining. He had hoped

[1] Transactions of the American Institute of Mining Engineers, New York Meeting, September 1890.

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to have heard from the Authors facts as to the merits and demerits of lead-covered cable, cables run on insulators, and highly insulated cables contained in casing, with remarks as to their relative cost, durability, and damp-resisting qualities. He had obtained such good results from the use of bitumen as an insulator, that he had adopted, at Mr. T. O. Callender's suggestion, bitumen-covered cables laid in heavy wooden casing in a large mine installation for light and power. With regard to the Authors' remarks as to separate lamp and power circuits, the scheme seemed feasible for short distances, but in a large mine it would probably be found that the extra cost of laying and maintaining four cables instead of two would counterbalance any advantage which might accrue from the greater steadiness of the light. In his experience power was the primary object in a mine, and light was a secondary consideration, and the steadiness or unsteadiness of the lamps would only affect the number of hours they would last. There was one consideration in connection with the ventilation question which had been omitted by the Authors, viz., that the exhaust air from a compressed-air motor was purer than would be obtained from a fan placed in the heading itself. This was noticeable in the case of long headings, and the necessity of forcing fresh air to the workings entailed the placing of the fan as near as possible to the entrance and the use of long air-pipes in which there was considerable loss by friction. He was using a 330-watt motor, driving a small Sturtevant fan at a speed of 1,800 revolutions, and forcing air along 150 to 200 yards of 6-inch pipe so as to keep the workings clear. As to electric rock-drilling by means of the percussion drill, it seemed that the Authors had had little practical experience in this direction. The plant illustrated might be useful in proving that the work was possible, but it by no means fulfilled the most important requirements of the case. The object of rock-drilling by electricity was to supersede hand-labour. The first essential was that it should cut into the rock quickly, and the second that it should be easily adjusted, otherwise the miner working by hand would catch up the electric drill after each hole, and no practical advantage would be gained. The Authors' plant was unwieldy, and involved much labour and loss of time in setting it in position. The flexible shaft arrangement might be useful for work of an intermittent character, but it was hardly a desirable piece of machinery to introduce into a mine. These remarks were based upon actual experience. Mr. Rooper would prefer a more compact, self-contained, and easily adjustable apparatus, designed upon the lines he had indicated. The best

Mr. Rooper.

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Mr. Rooper. work accomplished, by means of the description of plant illustrated, was the drilling of six holes 1 inch in diameter and 33 inches deep, in three hours and a half, including the time spent moving and re-setting the drill. The actual speed of drilling in slate rock was 2 to 3 inches per minute. With hand-labour the rate of progress was about ½-inch per minute. There was therefore reason to believe that electrical machinery might be profitably applied to this purpose.

Mr. Steavenson. Mr. A. L. STEAVENSON observed that the subject of the transmission of power in mines had occupied his attention for nearly forty years. His present impression was that fuller tests would prove electricity to be inferior to a well-contrived rope system, in respect of useful effect, partly owing to the high speeds of the dynamos, which had to be reduced by toothed wheels or belts. Electricians seemed hardly to realise the extent of the danger if a fire should occur in the long, dark, thickly-timbered passages of a mine. The constant crushing and moving of the roof, floor and sides, must eventually affect the wires and their covering, and any fire there, with strong currents of air passing, would probably shut in for ever all the men behind it.

Mr. Stokes. Mr. A. H. STOKES said the employment of electric motors in mines had for a long time been seriously delayed by the anticipated danger from sparking, and this especially applied to workings in which fire-damp was occasionally found, or in which locked safety-lamps were used. It was clear that managers of such mines would hesitate to adopt electric motors, if the parts liable to sparking were less perfectly secured against the danger of inflaming fire-damp than the safety-lamps. The Authors appeared to think that in the case of an inrush of fire-damp, "means should be adopted to allow the machine to be stopped working, before this explosive gas has had time to come in contact with the commutator and brushes;" but it should be pointed out that the workman's first indication of explosive gas would be from the flame of his safety-lamp, and the fire-damp would have penetrated the box cover of a motor (unless it was hermetically sealed) as quickly as the safety-lamp. It was further probable that an inrush of explosive gas would instantly place the workman in the dark, and he would flee for his life, leaving the motor running. The coal-face was the most likely place in the whole of the mine at which to find outbursts of fire-damp, and hence such machines must be absolutely safe, without dependence upon human manipulation in cases of sudden danger. The idea of boxing in the motor, or covering it with wire-gauze, had been long known to mining engineers, but such

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methods had not yet obtained sufficient confidence to secure their general use. The encasing of motors in iron covers was open to the following objections: (1) The possibility of the volume of enclosed explosive mixture being sufficient, if ignited, to burst the covering; (2) The danger of a bad joint, through which flame might pass; (3) The leaving out of a bolt, or the faulty adjustment of the cover, by a careless workman; (4) The cover might be opened whilst the machine was running, or otherwise it might be allowed to work without protection, thus exposing the brushes to the atmosphere of the mine; (5) The time taken in opening and closing such covers when the brushes and commutator required cleaning; (6) The increased weight and size of the machine. Similar remarks applied to wire-gauze coverings, with the addition that they were liable to injury. If electrical motors were to be introduced in mines they must be so constructed as to be absolutely free from the possibility of igniting inflammable gases outside them, and for this reason a motor was required in which the brushes could not be exposed to the atmosphere whilst the machine was running, nor the machine run until the brushes were securely enclosed by an absolutely flame-tight joint. The locking arrangements should not be dependent upon a workman, but should themselves govern the working or stopping of the machine. Mr. Stokes.

THE AUTHORS, in reply to the Correspondence, pointed out that Mr. A. H. Stokes, while calling attention to the probable danger in fiery pits, arising from electric sparks, appeared to overlook the fact that, although sparking did occur at the commutator, it was under abnormal conditions, such as the breaking of a wire on the armature, that it was really dangerous, and these would not be provided against by the covering in of the commutator in the method he described. He was entirely mistaken in his statement that fire-damp would penetrate the covers of the motor as quickly as the safety-lamp, as their experiments showed that the gas would take probably twenty hours to produce an explosive mixture inside the covering, in which time, even should the man leave the machine, it could be turned off at the top without trouble. The answers to the objections of Mr. Stokes were as follows:— The Authors' reply.

(1) Was a possibility, not a probability.

(2 and 3) The covers were so arranged that, if they were on at all, they were properly adjusted.

(4) Could be provided against in the same way as in Mr. Stokes' suggested arrangements, either by locking the cover or by attaching the brushes to it, so that when it was off the circuit would be broken.

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The Authors' reply.

(5) Was not material unless it should prove a practical objection to the working of the machines, which had not hitherto occurred.

The Authors did not know whether Mr. G. Fowler had had much experience in carrying steam in underground workings; they could only say that they had already replaced several pumps and other machines working with steam, owing to the discomfort caused by the heat and leakage of steam when carried underground. The objection to carrying ropes down the shaft of a colliery, particularly at high speeds, and the danger in the narrow roadways to men or animals in the event of a rope breaking, was sufficient to prevent any extended application of this system. In reference to the coal-cutting machines, the Authors might state that they had never yet seen one with the cutter-bar blocked. They used a double cable, and did not employ the rails to form the return circuit.

10, 17, and 24 February, 1891.

SIR JOHN COODE, K.C.M.G., President,
in the Chair.

The discussion on the Paper by Messrs. Llewelyn B. and Claude W. Atkinson, on "Electric Mining-Machinery," occupied these evenings.

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LIST OF MODELS, &c.,

EXHIBITED IN ILLUSTRATION OF MESSRS. ATKINSON'S PAPER.

February, 1891.

Exhibitor.	Objects.
Aqueous Works & Diamond Rock-boring Company	Boring-crown.
	Cores.
	Photographs of boring-machines.
Robt. Limpett Anderson .	Gauze lamp used to examine the workings at Blantyre Colliery on the occasion of the explosion of fire-damp on the 22nd of October, 1877.
James Ashworth	Safety-lamps (8).
Reginald Bolton. . . .	Working model of American ore-crushing machine.
Hy. Bramall, M. Inst. C.E..	Rivet-moulding machine for making lead rivets for securely locking safety-lamps.
	Working model of Holcroft's safety-cage and detaching-hook.
	Working model of Owen's safety-cage.
Bennett H. Brough . . .	Photographs (3) taken in the mines at Clausthal-am-Harz, Germany.
John Brown & Co. . . .	Pair of forged-steel wheels and axles.
Rev. G. M. Capell, B.A. .	Hand mine-ventilator.
	Mine friction-test tube.
	Working model of Capell fan.
Robt. E. Commans, Assoc. M. Inst. C.E.	Grips and knot for Otto's aerial ropeways.
	Model of stamping-machine.
	Safety-lamp.
Cox-Walkers	Electric miners' bells and generators.
John Davis & Son . . .	Anemometers (Biram and self-timing).
	Clinometer (Louis Improved Davis's).
	Improved Hedley Dials, with Hoffman tripod heads, for instantaneous setting-up and levelling.
	Safety-lamps constructed in accordance with the new Mines Act.
	Switches, switch-boards, and various electrical fittings.
	Theodolites and levels, with Hoffman tripod heads.
Thos. Docwra & Son. . .	Crowns with extractors.
	Samples of core.
	Working model of diamond drill machinery.
Foote & Von Buch . . .	Working model of tram-line on 'Series' electrical system.
Fowler-Waring Cables Company	Cables suitable for mining purposes.

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Exhibitor.	Object.
General Electric Power & Traction Company	Portable motor for mining purposes.
W. T. Goolden & Co. . .	Bar armature (61 unit), pedestal, and spherical ohm-meter and generator for testing insulations, with sunbeam lantern and lamp for wet and dry situations.
	Coal-cutting bars and tools.
	Electric coal-cutting machines, with rotary coal-drill, grinding-jig, brush-holders, and carriers.
	Electrical measuring instruments, including Cardew voltmeter, and direct-reading anometers and voltmeters (Evershed's).
	Electro-magnetic separator.
	Enclosed mining-motor.
	Resistance-frame for regulating current.
	Switches made for the Brighton Corporation.
G. J. Lampen & Co. . . .	Clip-pulley for rope-haulage in mines.
	Corf-greaser.
	Model of steel corf.
	Safety-lamps (2).
	Signal-bell.
Le Gros, Mayne, Leaver & Co.	Ingersoll rock-drills (2).
London Electric Wire Company	Insulated wires and cables suitable for electrical work in mines.
Ewing Matheson, M. Inst. C.E.	Chinese translation of part of Matheson's "Aid-book to engineering enterprise."
Mining and General Electric Lamp Company	Electric miners' lamps (4) and batteries made of this company's 'lithanode.'
James Pitkin	Electric miners' lamps (6).
	Explosive-gas detector.
C. E. Rhodes, M. Inst. C.E. .	Safety-lamps (31).
Roburite Explosives Company	Specimens of cartridges, &c.
J. R. Schram, M. Inst. C.E. .	Rock-boring machine on tripod.
Lieut.-Col. J. D. Shakespear, Assoc. Inst. C.E.	Safety-lamps (4).
Siebe, Gorman & Co. . . .	Life-size figure of miner in 'Fleuss' noxious-gas dress.
Henry Simon, M. Inst. C.E. .	Model of 'Simon-Carvès' coke-oven.
M. Theiler & Sons . . .	Recording water-level apparatus.
Evan Thomas & Williams .	Safety-lamps (Cambrian & Bonneted fireman's).
William Thomas, Assoc. M. Inst. C.E.	Elliot's locked-wire rope welded by the Thomson-Houston process.
James Thorne.	'Thorneburry' safety-lamp.
Wellington & Co. . . .	'Gates' rock and ore-breaker.
Woodhouse & Rawson United	Miners' bells.
	Safety-lamps and lanterns.
	Switches and switchboards.

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"Indian Bridges."[1]

Additional Correspondence, and Replies of the Authors.

Mr. C. O. Burge remarked that Mr. Stoney's Paper on the New Chittravati Bridge was especially interesting to him as describing the reconstruction of one of a series of large bridges on the north-west line of the Madras Railway, of which, with one exception, he had charge when he was Resident Engineer on a maintenance division of that railway, and one of which, that over the Hugri, he partly constructed. They were the Cheyair Bridge (38 openings), the Pápaginí Bridge (20), the Chittravati Bridge (40), the Pennár Bridge (24), the Hugri Bridge (34), and the Tungabhadra Bridge (58 openings). These openings measured 70 feet from centre to centre of the piers, or about 64 feet clear between them. The original bridges were remarkable for having a great number of comparatively small spans, and for the cheapness of their construction, the cost per lineal foot being less than one-third of that of the bridge described in the Paper; the Pennár Bridge for example, only costing R.153, the Chittravati Bridge R.149, and that over the Toongabudra R.168 per lineal foot. The adoption of small spans made it possible to erect the girders at the back of the abutments, and roll them in sets of two continuous spans, over the piers to their respective places, and considerable economy was effected in this manner. The piers were of three types, viz.: (1) masonry built direct in the solid; (2) masonry on a group of small shallow brick wells; (3) screw-piles of wrought-iron. The piers of the Cheyair Bridge were undermined in a terrible flood more than twenty years ago, when the night mail train rushed into the gap with frightful loss of life, the Pápaginí Bridge had been partially or wholly reconstructed, the Chittravati Bridge failed in October 1874, as described in the Paper, and that over the Pennár was carried away on the 16th October 1889, and was now replaced by one very similar to the new Chittravati Bridge. Structures with more substantial piers and fewer of them in the first instance, would have been more durable, and it seemed, from the fact of the girders referred to in the Paper having been safely

Mr. Burge.

[1] Minutes of Proceedings Inst. C.E., vol. ciii. pp. 123–200.

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Mr. Burge. erected in the river bed, that little advantage was gained by the original erection on shore of the older bridges; for, as regards floods, all these rivers were of the same character. The failure of the original bridge over the Chittravati was evidently attributed to the insufficiency of the depth of the piers, and not to deficient waterway, as the new bridge was 164 feet shorter, deducting piers in both cases, a difference hardly accounted for by the fact that the old one was slightly skew to the channel. The Author was right in pleading for more latitude with regard to the dimensions of cylinder work, so as to allow for unavoidable divergence in sinking. Mr. Burge had drawn attention to a somewhat similar point in his Paper on the Hawkesbury Bridge, and in the correspondence upon that subject his opinion was supported by Messrs. Bouscaren, Collingwood, and Professor Gaudard.[1] Considering the nature of the strata passed through, the sinking of the cylinders at R.58½ per lineal foot seemed to be remarkably cheap, and reflected great credit on the Author, as it must be inferred from the fact that no contractors were mentioned, that the work was carried out departmentally. It would appear from the Paper that the piers above ground were of iron with masonry inside, and it might fairly be asked why the stonework was not exposed, the Nirgee limestone of which it was composed making very presentable masonry. Mr. Burge had not gone into the question of the quantity of metal provided for the stresses in the girder members, but it would appear from the small deflection of $\frac{1}{3360}$ of the span with a maximum load that the erection of the structure at the maker's works and on the spot had been well carried out.

Mr. Robertson. Mr. ROBERTSON, in reply to the remarks that had been made as to the absence of information regarding the design, loads, and permissible strain, pointed out that the Paper dealt, as its title showed, solely with that part of the work with which he was connected, namely, the erection of the Lansdowne Bridge. The contract for the ironwork had been let before the Author was deputed to consider the erection. The cost of the ironwork was due partly to the fact that most of the members required some special shaping, and partly to the expense of putting it up in England, which might be considered a necessary preliminary in consideration of the locality for which it was designed. There being only a single span to the bridge enhanced the cost of erection, as special appliances, such as the central staging, were

[1] Minutes of Proceedings Inst. C.E., vol. ci., p. 2.

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only available for a small tonnage. In reply to Mr. Young, considering the position of III strut and that its length was 230 feet, and weight 120 tons, it would have been difficult in any case to have lifted it in one piece, and the details of construction rendered it impossible in this particular instance. There was no difficulty in setting the nose of III strut to exactly the right span for the horizontal tie, when once it was completed and the distance measured. The 1½-inch rope was only a guy to hold the head of each piece after it was raised into its place, so as to prevent any strain on the fastenings; and it was not intended to imply that the rope lifted the piece. With reference to the suggestions that an arch or a girder would be preferable to a cantilever, there was no doubt that the site lent itself to an arch; but in balancing the advantages it must be remembered that each day's work on a cantilever was secured, while in the case of an arch the risk continued till it was closed. As for a girder, it would have been quite impossible to erect false works in the Rori Pass, and such a proposal was never made among the numerous schemes for bridging the Indus. In reply to Mr. Read, the deflection under the test-load (two of the heaviest locomotives and fully loaded wagons placed so as to produce the maximum deflection at the nose of the cantilever) was 2½ inches. Deflections were observed at all the panel points simultaneously by a water-pipe fitted with a gauge-glass at each, the most important being checked by an observer with a level. The oscillation was recorded by a seismograph, and only amounted to $\frac{7}{16}$ inch at a speed of 35 miles per hour, which was the utmost that could be attained by the test train owing to the gradients leading up to the bridge. It was true that there was an oscillation of 1¼ inch under a crowd, though the bridge was steady with the train. This was due to the absence of lateral bracing on a part of the cantilever where it only extended between the secondary members. This deficiency having been supplied in those bays, the oscillation was reduced to ⅜ inch under a crowd marching in step on the footways only—the arrangement which had previously given the greatest oscillation. A larger crowd all over the floor only produced an oscillation of ⅛ inch, as did also various combinations of train and men. Before this bracing had been added, an opportunity occurred of testing the effect on the bridge of as heavy a storm as had been experienced in those parts, while a goods train was passing; the direction of the wind being inclined at 45° to the bridge. No oscillation was perceptible.

Mr. Robertson.

In reply to Mr. Claxton Fidler, the gallows itself had a pro-

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Mr. Robertson. jecting arm to work a rope for the heel of raking-pieces as shown in Fig. 8, Plate 6, in plan and front view. A very convenient tool which was much used was a spar or tube furnished with an ordinary jack head at each end and rings to sling it by; these were provided of different lengths and used to boom out pieces. In the event of its being desired to raise a piece from a position on the floor of the bridge where it could not be reached by the overhead rope, an ordinary block and tackle hooked on the traveller on the top was used. A pair of wire-rope tackle sets were provided for this purpose. A good deal of lifting of small pieces was done with ordinary ropes working from the overhead gear. The Paper would hardly be complete without some notice of the accuracy of the work as executed by Messrs. Westwood, Baillie and Co., which enabled the most intricate joints to be brought together without difficulty.

Mr. Stoney. Mr. STONEY thought there could be no doubt that the use of small charges of dynamite facilitated cylinder sinking, and reduced the loads required by perhaps 30 per cent. The same system was used at the Pennár Bridge, having been introduced by Mr. R. E. Ellis, Assoc. M. Inst. C.E., the Author's assistant on that work. With regard to Mr. Wolfe Barry's query, there was no doubt of the fact that in one instance, after 30 feet of concrete had been put in, there was a depth of 8 feet of slurry formed over it; no analysis was made of it, but when taken out and poured on the river-bed it dried like fine mud. It was produced only in the case of one make of cement. Referring to Mr. Robinson's remarks, there was, in the absence of suitable pneumatic plant, no means of getting the large boulders out from under the cutting edge, except by blasting, as they were too large to push out or to chip, and if they were undercut and drawn into the cylinder blows of sand followed, as happened at pier No. 11. The cylinder served merely as a casing to allow of a concrete pillar being carried to the rock bottom, so that its having cracked was of no material consequence. It might be mentioned that the wrought-iron cutting-rings were not cracked by the dynamite, but their lower edges often got crushed by coming forcibly in contact with boulders or rock, when the cylinders ran down under heavy loads. With regard to Mr. Riddell's remarks, the Author had designed an annular plate to carry internal loading, Figs. 12 and 13, Plate 7, and used it very successfully in three cylinders of the north abutment, and he would have liked to adopt this plan all through, but the work had been already commenced, and there was no time to wait for castings from

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Madras. The Author was fully alive to the advantages of internal loading, and always advocated it, because, 1st. It kept the centre of gravity of the load low, and saved the great cost of stacking and unstacking rails, which moreover brought the load high above the river-bed, thus increasing the tendency of the cylinder to cant. 2nd. It made use of the permanent filling as a sinking load, and this filling could be built in above water and inspected, instead of having to be put through water by skips. In connection with Mr. Wrightson's remarks, the Author had known cylinders in the Pennár and Cheyair Bridges to sink suddenly without any apparent cause, after resisting the action of a heavy load for days, during which time they had remained untouched. Mr. Stoney.

In answer to Mr. Gillott, 8 per cent. more rivets were used than were actually inserted, including all those that were lost or burned in heating. The number of loose rivets cut out was about 4 per cent. The Author would have been glad to have the furnaces and riveters described by Mr. Gillott instead of the ordinary portable forges which were used. With reference to the remarks of Mr. Macdonald and Mr. Seyrig, it should be explained that the section of the river-bed shown by the original borings was not only often quite wrong in depth, but very misleading as to strata, giving for the most part no indication of the existence of the boulder beds actually met with. For example, at pier No. 11, a depth of 6 inches only of dark boulders was shown by the borings, while 22 feet of them was actually sunk through, without reaching the rock. Piers Nos. 12 to 18 went through layers of boulders varying from 6 to 14 feet in depth over the rock, while the borings indicated none. The working section showed materials suitable for dredging throughout, and it was only when a considerable part of the cylinder-sinking had been done that the existence of the bed of boulders became known. It was then too late to procure suitable pneumatic plant from England, as including the time necessary in order to obtain Government sanction, &c., it could not have been got out in less than nine months at the least. American and English Engineers could not easily realize the peculiar difficulties of working in India, where all plant had to be ordered from England, and machine shops for repairs might be 200 miles or more distant. There was also the greatest difficulty in procuring skilled labour and trained foremen and mechanics, so that the Engineer had to see personally to everything, including minute details, as well as to direct and supervise. The pneumatic work was done with old pumps imported in 1877,

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Mr. Stoney. the valves of which were worn and constantly broke down, allowing the cylinders to fill with water, which had to be again forced out; and this had to be done by native labour trained on the spot, without the supervision of a skilled foreman, so that the cost was consequently abnormally high. The Author would like to hear from Mr. Macdonald and Mr. Seyrig what the cost per lineal foot of sinking 12-foot cylinders to a depth of 50 to 60 feet below water-level should be with skilled labour and modern pneumatic plant.

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SECT. II.—OTHER SELECTED PAPERS.

(*Paper No. 2492.*)

"The von Schmidt Dredge."

By GEORGE HIGGINS, Assoc. M. Inst. C.E.

IN a Paper on "Dredging Operations and Appliances," by Mr. John James Webster, read before the Institution in 1887, under the head of "Sand-pump Dredgers," mention was made of the invention of Colonel A. W. von Schmidt, of San Francisco, and a scant description, accompanying a somewhat incorrect illustration, was given of the machine.[1] It is intended now to describe the invention more fully.

"Sand-pump dredgers," or "suction-dredgers," or, as they are sometimes called, "hydraulic dredgers," have been known and used for many years, and have done good work in gravel, sand and silt; but Colonel von Schmidt's machine is the only one which will deal with clay as well as with loose materials. Nearly all hydraulic dredgers employ centrifugal, or "whirling" pumps, which have two advantages over stroke-pumps, viz., (1), that all valves are dispensed with except one foot-valve, and (2), that the action is continuous in one direction, so that the suspended material has no opportunity of settling; whereas in a stroke-pump there is a sudden stoppage and a change of direction at the end of each stroke.

The first von Schmidt dredger employed in Australia, the "Elwood," was built by the Author for reclaiming the Elwood Swamp at St. Kilda, a suburb of Melbourne. Its first work was that of excavating a ship-canal and dock across the West Melbourne Swamp for the use of the Victorian railway department. It is still engaged there.

The "Elwood" was constructed in Melbourne. The hull, of Oregon timber, H H, Plate 6, is 100 feet long, 50 feet wide, and 9 feet deep; flat-bottomed, sides and longitudinal bulk-heads 12 inches

[1] "Dredging Operations and Appliances," by John James Webster, M. Inst. C.E. Minutes of Proceedings Inst. C.E., vol. lxxxix. p. 8.

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thick; ends semicircular, 16 inches thick. The longitudinal bulkheads divide it into three main compartments, the centre space being occupied by the boilers, main engines and pump, while those on either side are divided up into coal-bunkers, water-tanks, cabins, &c. The boilers, B B, are of the marine type, and work at a pressure of 120 lbs. per square inch. The whirling-pump, C P, stands on end, and is about 14 feet high, the runner being 10 feet in diameter. The suction-pipe is attached to the centre of the casing, the discharge-pipe leaving the pump on the top. The pump is driven by compound condensing engines, E E, of 24 inches stroke, the high- and low-pressure cylinders being 20 inches and 36 inches in diameter respectively. They are mounted upon a Δ frame, the connecting-rods of both cylinders grasping the same crank-pin. The speed varies from 120 revolutions a minute at long discharges to 100 at short ones. They indicate from 420 to 330 HP., according to the speed. The Blake surface-condenser, S C, is driven by a separate steam-engine mounted on the same frame with the air- and circulating-pumps. A donkey-boiler, D B, is used for many purposes. A Worthington pump, W P, is employed for priming the whirling-pump, and for filling the tanks with fresh water, bilging, &c. A pair of engines, S E, with cylinders 10 inches by 6 inches, give motion, by means of spur-gearing, to a shaft which has on it two chain-drums and two winch-ends. The chain-drums are used for lifting the "spuds" or piles which hold the dredge steady while at work, and the winch-ends are employed for moving it about by pulling on the mooring-ropes when the spuds are raised, and also for general hoisting-purposes.

The arrangements which distinguish the von Schmidt machine from all other suction-dredgers, and which enable it to do work that none of the others can do, are situated on deck. The suction-pipe is bent upwards a short distance from the pump, and, at this bend, a gland and stuffing-box are introduced, enabling the outer end to move horizontally in a semicircle about the gland as a centre. The movable part of the suction-pipe is placed upon a carriage or table, T, which travels to and fro on rollers around the semicircular bow of the dredge. The pipe lies horizontally upon the table, and its outer end, which is telescopic, hangs vertically over the bow, and can be raised or lowered at will. The lowest of the telescopic pipes has a bell-mouth or "hood," B M, 8 feet in diameter, placed eccentrically with regard to the suction-pipe, but concentric with an 8-inch steel shaft, K S, which, passing down outside the telescopic pipes, and through the centre of the hood, drives the horizontal wheel to which the knives, K K,

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are bolted. Collars on the shaft keep the knives at a fixed distance below the hood. The upper part of the shaft is square, and slides through the bevel wheel, B W, as the telescopic pipes are lowered or raised. The traversing motion of the table, the rotation of the knife-shaft and the lifting of the telescopic pipes are all performed by means of the table engines, T E, which are mounted upon the suction-pipe. The cylinders of these engines are placed at right-angles on a Δ frame, and are each 12 inches in diameter, with 12 inches stroke. They are connected with the condenser, but may, at will, be permitted to exhaust into the atmosphere. The table traversing-gear, and that for lifting the telescopic pipes, as well as that for driving the cutting-knives, will easily be understood from the plans. Belts, friction-clutches, and some toothed gear are employed. The only valve in the suction-pipe is that shown at V, which is particularly easy of access. The portion beyond this valve, going towards the water, is primed by means of a steam ejector, or by being connected with the condenser, while the other part is filled at the same time as the main pump by means of the priming-pump, W P, already mentioned.

The discharge-pipe, D P, is of wrought-iron, and is 21 inches in diameter. On leaving the pump, it passes over the house and downwards over the vessel's side, where an elbow on a swivel connects it with a line of pipes floating on pontoons. Ball-and-socket joints of cast-iron are used to connect these floating pipes together, and between each pair of pontoons is placed a short length unsupported except at its jointed ends. This arrangement is sufficiently flexible to admit of the dredge being moved about over a large area without any stoppage to alter the pipe-line. On shore, wrought-iron pipes of a very simple description are laid on the ground so as to follow its undulations.

The area where the mud is deposited is, in the first instance, enclosed by retaining-banks, and one or more weirs provided for allowing the water to flow back after the mud has settled. Bricks, stones, bolts, pieces of iron, nail-cans, shovels, &c., are sometimes found issuing from the discharge-pipe. Lumps of iron, weighing 6 or 8 lbs., have come up along with the mud, and have been afterwards removed from the pump.

The following is a description of the method of working the machine. The dredge is floated into position, and placed so that its bow (or suction-pipe end) nearly touches the bank which is to be cut away; the two spuds are allowed to drop through their sockets, and their iron-shod ends stick into or rest upon the material in the bottom of the channel. A rope

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is carried from the foremast head over the table, and made fast to some mooring placed in the direction towards which it is intended to work. Four other lines are put out from the sides and attached to moorings. The whirling-pump is primed, as before described, and the main engines, which drive it, are started. The table engines are then set in motion, causing the knives to revolve. The knives are brought into contact with the bank by moving the table sideways, and the material which they cut is carried up the pipe by the rush of water, passing through the whirling-pump and the discharge-pipe to the shore. The presence of the solid substances is at once indicated by a vacuum-gauge attached to the suction-pipe. The knives are kept at one level usually, and move with the table as far as it will go in one direction, when they, together with the telescopic pipes, are lowered a distance of from 6 inches to 36 inches, according to the hardness of the material, and are then carried back, still cutting their way, to the other side. When there another lowering of the knives and telescopic pipes takes place, and the process is repeated. At each traverse a strip of ground, 60 feet long by 10 feet wide by from 6 inches to 36 inches deep, is swept up. The to-and-fro motion of the table, with the knives and suction-pipe, is continued without moving the dredge, until the desired depth is reached. The "Elwood" has been made capable of dredging to a depth of 24 feet, but this limit could be exceeded by using longer pipes. The desired depth having been reached, the telescopic pipes are lifted up; then the spuds are raised off the bottom, the dredge pulled forward 9 or 10 feet, and the spuds again dropped, and the cutting commenced. One minute is long enough to make this change, the main pipe meanwhile discharging water. In this way the dredge cuts through a piece of ground 60 feet wide. In plan, the shape of this excavation is usually an arc of a circle, the centre of which is the ball-and-socket connection between the floating and the shore-pipes. When the excavation has been carried as far as necessary, floating-pipes are added or withdrawn, and other patches, 60 feet wide, are taken out alongside the first. It will be seen that this method ensures the bottom of the channel being left quite level, without lumps or holes.

Occasionally, an examination is made of the cutting-knives, which are brought up out of the water by letting go the chain on one side of the telescopic pipes and heaving up on the other, by which means they, together with the vertical knife-shaft and knives, are swung up to one side; a ball-and-socket joint on

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the horizontal part of the suction-pipe, and two universal joints on the horizontal shaft above it, being provided in order to allow this motion to take place.

The von Schmidt dredge can work by night almost as well as by day, but daylight is generally chosen for adding or withdrawing lengths of discharge-pipes.

The machinery of the "Elwood" being quite new, there were a good many delays during the first few months, owing chiefly to defects in the main engines. More than half the working time may be taken as having been lost up to the present. The actual work done up to the 14th July, is given in the following Table:—

Date.	Number of Engine Hours.	Length of Discharge-Pipe.	Quantity.
		Feet.	Cubic Yards.
December 1889 . .	71	4,000	15,340
January 1890. . .	121	3,000	25,930
February „ . . .	199	2,500	42,830
March „ . . .	275	1,300	56,000
April „ . . .	373	1,600	70,800
May „ . . .	130	2,000	17,200
June „ . . .	292	2,000	61,000
July (1 to 14) . .	168	1,000	31,000
Totals . . .	1,629	..	320,100

A von Schmidt dredge of smaller size, with 12-inch pipes, is being built at Christchurch, New Zealand, by the Gillespie Beach Gold Mining Company, the intention being to lift wash-dirt from a river-bottom and beach. The application of the system to gold and tin-mining is one that promises to develop extensively.

Another dredge, with 9-inch pipes, is now afloat on the Albert Park lagoon, which it is proposed to deepen, while use will be made of the dredged material to raise some low-lying lands in the vicinity.

The Paper is accompanied by a photograph and two lithographed drawings, from which Plate 6 has been prepared.

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(Paper No. 2500.)

"On the Application of Governors and Fly-Wheels to Steam-Engines."

By Professor VICTOR AUGUST ERNEST DWELSHAUVERS-DERY, of Liége University.

Translated by BRYAN DONKIN, Jun., M. Inst. C.E.

IN a previous Paper,[1] the Author endeavoured to show how a governor, or tachometer, applied to a steam-engine, might be experimentally studied. He had demonstrated that no practical theory of the governor could be established unless the resistance R, which the sleeve encounters in one direction during its upward, and in the contrary during its downward tendency is taken into consideration. On account of this unavoidable resistance, he showed that the sleeve might remain without moving in a certain rigid position, while the rotatory-speed of the governor or of the engine fluctuated between the limits of—1st, the greatest speed w, corresponding to the instant when the centrifugal force of the balls establish an equilibrium with their own weight, the weight of the sleeve, and the resistance + R; and 2nd, the least speed v, corresponding to the instant when the weight of the balls and of the sleeve establish an equilibrium with the resistance − R, and the centrifugal force, diminished by the decrease in the velocity. Thus the governor does not respond to the variations in the speed comprised between w and v, and its "coefficient of sensibility" may be defined as the proportion between the mean speed of the governor, and the difference $w - v$ of the two velocities of equilibrium $\frac{w}{w - v}$.

There are therefore two velocities of equilibrium instead of one, as maintained by the old theory, a proposition which rendered it impossible to give a rational definition of sensibility. The sensibility of a governor depends upon the resistance R, which is in

[1] Minutes of Proceedings Inst. C.E., vol. xciv. p. 210.

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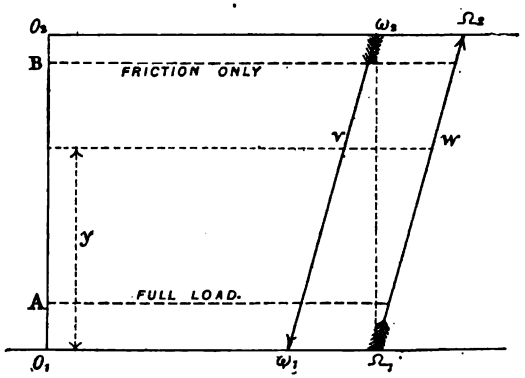
its turn dependent upon the kind of communication interposed between the sleeve of the governor, and the valve modifying the motive power. The sensibility depends upon the internal friction of the tachometer itself. Given a governor and the resistance R, a diagram may be traced of the two velocities of equilibrium v and w, the abscissæ of which will be in proportion to the velocity, and the ordinates to the height the sleeve reaches in its travel. In some governors the lines of these diagrams are almost straight, like those marked with thick lines in *Fig. 1.* The stops of the sleeve confine it to the two positions o_1 and o_2. At the position o_1 we will call the values of v and w respectively ω_1 and Ω_1. At the higher position o_2 they are marked ω_2 and Ω_2. Thus the smallest velocity of equilibrium is ω_1, and the greatest Ω_2, and

Fig. 1.



the governor acts only between these limits; the space between them constitutes the allowed irregularity of the instrument.

In the "Théorie Nouvelle des Régulateurs," published in 1877 by Mr. Charles Beer and the Author, and in the Author's Paper before mentioned, attention was called to these definitions of sensibility and regularity, and also to a quality indispensable to all steam-engine governors, called "astaticity." It may be thus described. With its full load on, the engine ought to be capable of running at the mean velocity ω; it ought also to run at the same velocity with no load but its own friction; and, lastly, it ought with an intermediate load to run at the same speed, between the maximum and minimum limits Ω_2 and ω_1. Clearly this result will, with an astatic governor, be obtained under the following conditions:—

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1. When the sleeve is in its highest position o_2, all admission of steam will be stopped.

2. When the sleeve is in its lowest position o_1, the maximum quantity of steam will be admitted, and will be more than that required for the maximum load of the engine. (This second condition was omitted by the Author in his former Paper.)

3. In order to make the governor practically as sensitive as possible, and at the same time to satisfy these two conditions, the two intermediate velocities Ω_1 and ω_2 are made equal to each other, and both are made equal to the mean angular velocity ω.

The Author has cited examples to show that a governor might be so constituted as to make it astatic, that is, acting under the best conditions, the diagram having the shape shown at *Fig. 1.* But although he had discussed the question in 1872,[1] he did not then touch upon the limits of speed to be chosen, and the relations to be adopted between the governor and the fly-wheel. In the engines now used for electric lighting, the whole load may be thrown suddenly on or off the engine, and it must be constructed to bear these extremes, without allowing the velocity to exceed or fall below the two limits assigned. The consideration of this question forms the subject of the present Paper. In the following remarks the resistance R to the movement of the sleeve will be placed among the data given, although it is often difficult to estimate it in practice. Usually it can be measured experimentally on an engine, and reduced by means of levers, &c., to suit any special tachometer.

It has often been said that the sensitiveness of the fly-wheel ought, under ordinary conditions, to be greater than that of the governor, otherwise the sleeve of the latter would move, although the number of revolutions did not vary, and this might affect and disturb the admission of steam at the critical moment. The Author does not attach an exaggerated importance to this consideration. To change the admission of steam, the governor has but the actual period of admission, which is very short in large expansive engines; and if during expansion the velocity of the engine has changed, all that is required is to adjust the governor, that it may regulate the admission at the next stroke. The important point is to know how the governor will act when variations occur in the velocity during expansion, because, from the very beginning of the following stroke, the sleeve ought to take up a proper position, in order to adjust the admission of steam

[1] Revue Universelle des Mines, May 1872.

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to the ratio required by the modified load on the engine. The governor therefore should be regulated to act with precision in extreme cases, and its proper working under ordinary circumstances will then be placed beyond a doubt. It ought to agree with the fly-wheel, and, as long as the boiler furnishes steam to the cylinder, to prevent the speed exceeding the limits assigned.

The following are the extreme cases to be allowed for:—

1. When the engine is running with full load on at the velocity ω, the sleeve of the governor ought to remain stationary at the height A towards the lower end of its travel; but if the need arose it ought to be able to fall a little lower in order to restore the velocity, should there be a slackening of the speed through any unforeseen cause, such as a slight diminution of pressure in the boiler.

2. When the engine is running with no load but its own friction, and at the normal velocity, the governor ought to remain stationary at a height B, a little below the highest position o_2, because in case of need, the sleeve ought to be able to rise still higher, and cut off the admission steam, in order to restore the normal speed should the velocity be increased by an increase of boiler-pressure.

3. When the engine is running with its full load, and at its normal velocity, the whole load is suddenly thrown off, just at the beginning of expansion. In this case the governor cannot prevent an acceleration of speed, since it does not act during expansion. At the end of the stroke, if the fly-wheel is light, the velocity will be greatly increased, if it is heavy the increase will be small. It is desirable, in any case, that the governor should, during expansion, have reached the highest point in its travel, in order to suppress admission during the following stroke. Therefore from the beginning of the next stroke the velocity will diminish, until probably after slight oscillations, it becomes equal to the normal speed. On this account the maximum velocity of equilibrium, Ω_2, in the upward stroke of the sleeve ought to be smaller than that acquired by the engine at the end of the stroke now under consideration.

4. When the engine is running with no load but its own friction, and at the normal velocity, the whole load is suddenly thrown on just at the beginning of expansion. It is impossible for the governor to prevent the speed diminishing until the next stroke; the greater or less mass of the fly-wheel alone will, for the moment, limit the decrease in the velocity. In any case it is desirable that the governor should, during expansion, fall to the

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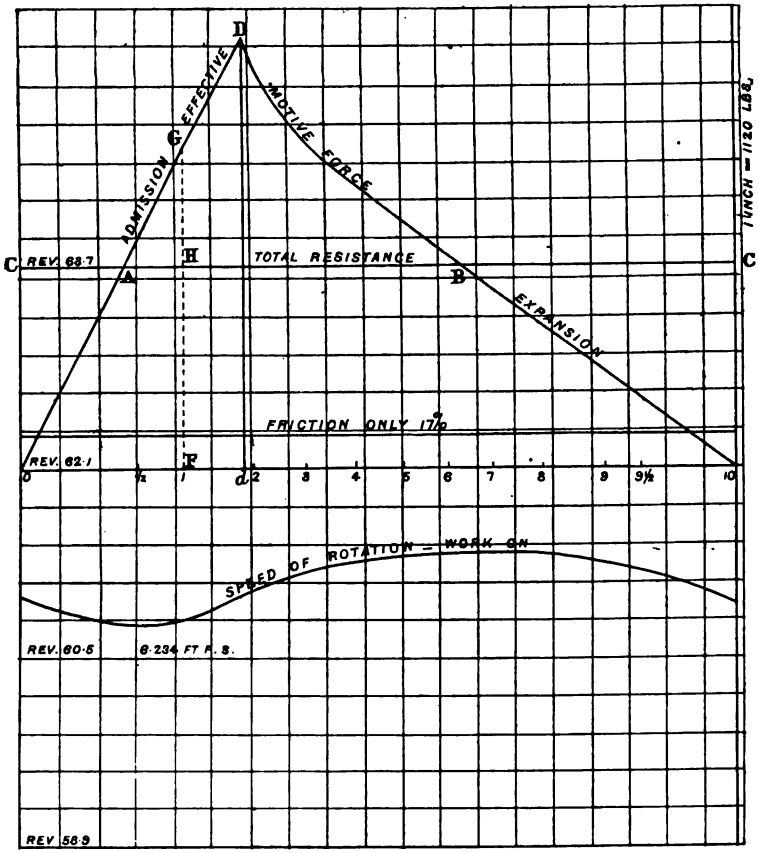
lowest point of its travel, in order to admit the maximum quantity of steam, and be able, even with the maximum load, to increase the velocity, which had fallen below the normal rate. For this reason the lower stop ought to be below the position that corresponds to the admission agreeing with the maximum useful load at the normal velocity. It is therefore necessary to make the

Fig. 2.



lowest limit of the governor's velocity ω_1 greater than that acquired by the engine at the end of the stroke, during which the whole load had been suddenly thrown on at the beginning of expansion.

The problem of the regulation of the governor of an engine

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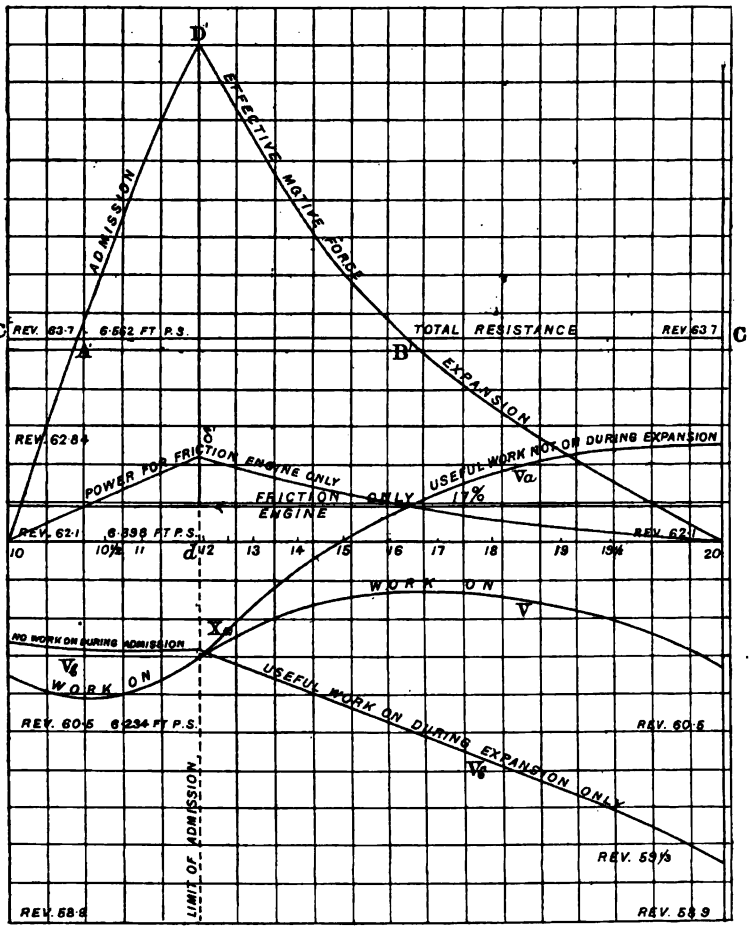
seems thus to be clearly defined, but does it lead to practical results? To ascertain this point the Author had recourse to experiment. He had at his disposal a steam-engine belonging to the Mechanical Laboratory of the University of Liége. Each

Fig. 2.



year he makes experiments on this engine, to determine the velocity of rotation at each instant of the stroke. Indicator-diagrams are taken, and the mean velocity, brake-power, and the distribution of the moving parts are calculated. The latter are divided into two equivalent masses; the one is rotating and

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calculated as if it were concentrated at the revolving end of the connecting-rod; this mass M is = 3,621. The other, the reciprocating mass, oscillates like the other end of the connecting-rod, or like the piston; it is here called m, and is equal to 16. Both these masses have a regulating influence on the rotatory motion. With certain engines Professor Thurston found the work consumed in friction per revolution was the same, whether the engine were running light or with full load on. Wishing to verify this fact, the Author made many experiments, and though unable to draw positive conclusions, he thinks that Thurston's law may be admitted without risk of inaccuracy. The brake-power represented 83 per cent. of the indicated work in these trials. Therefore the indicated work without any useful load was probably 17 per cent. of that with full load on, and this supposition was approximately confirmed by experiment.

By the help of the indicator-diagrams taken on both sides of the piston, we can determine the power exercised by the steam upon the piston, including the back pressure, at each instant of the two successive strokes of one revolution. The pressure of the steam on the piston must be resolved into its component parts to find its equivalent, which is supposed to be applied to the centre of the crank-pin, in the direction in which this point is moving, that is, tangentially to the circumference described. This component affords a measure of the total effect of the pressure of the steam to make the shaft rotate, which is the effective motive power E. *Fig. 2* gives the diagram of the motive power in the experiment in question. The abscissæ are proportioned to the angles described by the crank, starting from the dead point; the ordinates are proportioned to the values of E, and the area of the diagram to the work performed by the motive power to turn the shaft. This is merely a graphic representation of the results, calculated from actual data, and is used as a check, on account of the laborious nature of the calculations. It was found that the motive power in the forward stroke was 6,942·4 foot-lbs., and 7,353·4 foot-lbs. in the back stroke, giving a total of 14,295·8 foot-lbs. per revolution.

Since the engine is here supposed to be running at normal speed, it follows that the work of the total resistance per revolution is exactly equal to the work of the motive power. Generally the total resistance is also reduced to a constant force, and applied to the centre of the crank-pin tangentially to the circumference described. In this case the diagram representing the resistance will, with the same base as that of the motive power, be a straight

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line parallel to this base at such a height that the rectangle determined by it will have the same total area as the diagram of the motive power E. This straight line is C C′ C′ C, its height represents 2,311·6 lbs.

If it be wished to know the work expended in varying the velocity of the masses of the engine, from the beginning of a revolution to a given angle described by the crank, and represented by the length *o*F, the ordinate FHG must be drawn out, and the work T will be represented by the difference of the two areas *o*FG*o* and *o*CHF*o*. If the speed V_o of the centre of the crank-pin at the beginning of the stroke be given, and the proportion between the length of the crank and of the connecting-rod, the speed V of the crank-pin, and *v* of the other end of the connecting-rod, can be calculated for every position of the crank from the beginning of the stroke. The fraction $\frac{v}{V} = k$ is a function of the angle, and can easily be calculated. By virtue of the principle of *vis viva*—

$$T = \frac{M}{2}\left(V^2 - V_o^2\right) + \frac{m}{2}v^2;$$

$$\frac{2}{M}T + V_o^2 = V^2\left(1 + \frac{m}{M}k^2\right);$$

and

$$V = \sqrt{\frac{V_o^2 + \frac{2}{M}T}{1 + \frac{m}{M}k^2}}.$$

The Author has thus reckoned the values of V for twenty-seven different points of one revolution, a laborious but not a difficult task. The variations of velocities V are clearly marked in the diagram, *Fig. 2.* The axis of the abscissæ for the diagrams of velocities is supposed to be 6·07 feet below the horizontal straight line that terminates the figure at the bottom.

The minimum velocity is at the point 10½: V′ = 6·2629 feet, corresponding to 60·76 revolutions per minute, and the maximum at the point 17, where V″ = 6·3534 feet, corresponding to 61·64 revolutions, the circumference described by the point of concentration of the mass M being 6·1845 feet. The mean velocity is 6·3088 feet, corresponding to 61·21 revolutions per minute, and the coefficient of regularity is $\frac{6·3088}{6·3534 - 6·2629} = 69·7$, say 70. The mean velocity closely approximates to the arithmetical mean

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between the extreme velocities. The speed at the end of the direct stroke is 6·279 feet, or 60·92 revolutions.

The axis of the abscissæ is numbered 0, 1, 2 . . . 19, 20, *Fig. 2*, corresponding to equal fractions of the stroke. The letters D, D′, *d*, *d*′, mark the beginning of expansion at each stroke. The work due to the motive power, the total resistance, and the friction, have been reckoned separately between two successive dividing points (including the points marked ½, *d*, 9½, 10½, *d*′, 19½). The total work performed between certain points is subjoined.

		Limits.	Effective Motive Power.	Total Resistance.	Friction only.
			Foot-lbs.	Foot-lbs.	Foot-lbs.
I. Forward Stroke.	During admission . .	From 0 to *d*	2425·3	2237·2	370·3
	„ expansion . .	„ *d* to 10	4517·1	4910·7	834·8
	„ the whole stroke	„ 0 to 10	6942·4	7147·9	1205·1
II. Back Stroke.	„ admission . .	„ 10 to d^1	2514 3	1895·2	312·1
	„ expansion . .	„ d^1 to 20	4839·1	5252·7	893·0
	„ the whole stroke	„ 10 to 20	7353·4	7147·9	1205·1

As the engine was horizontal and the parts fairly well balanced, no count was taken in the above calculation of the weight of the moving parts. With a non-balanced engine, the weight must not be neglected.

Having obtained the speed V during the ordinary work of the engine for each point of the stroke, and traced its appropriate diagram, the Author has by the same process, based on the principle of *vis viva*, calculated and represented by a curve (*Fig. 2*), 1st, the speed V_a of the back stroke during expansion, in the case of the useful resistance being suddenly suppressed at the beginning of expansion, and 2nd, the speed V_b during the whole back stroke, assuming the engine to be running empty during admission, and the whole of the useful resistance to be suddenly thrown on at the beginning of expansion. In such a case the speed at the beginning of the stroke is supposed to be equal to the mean speed 61·21 revolutions per minute. *Fig. 2* shows clearly the variations in these speeds, V_a and V_b. The diagram of the effective motive power when the engine is running empty at the normal speed of 61·21 revolutions, has not been traced from the indicator diagram experimentally obtained, but by taking each of its ordinates as equal to 17 per cent. of the corresponding

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ordinate when the engine is running with full load on. This method may be considered as practically accurate. The results are :—

	Feet.
In the 1st case the velocity V_a at the end of the stroke is .	6·476
„ 2nd „ „ V_b „ „ „ .	6·117
The first corresponds to . . . 62·84 revolutions per minute.	
The second „ . . . 59·34 „ „	

The first differs from the mean speed by 1·63 revolution per minute, the second by 1·87; the irregularity of the engine, therefore, in these two cases is 3·5 revolutions in 61·21 per minute, $= \frac{1}{17·5}$, or a coefficient of 17·5.

It is the fly-wheel which permits this variation, and the governor is absolutely powerless to change it. The latter can only prevent the disturbance from going too far; it ought to set matters right, first by restoring, and afterwards by maintaining the normal speed. How it should be adjusted, in order to perform this function, the Author will endeavour to show.

Starting with the first case, when the useful resistance is suppressed at the beginning of expansion during the back stroke, the sleeve of the governor should have reached its highest position at the end of the stroke, to stop admission for the following stroke. Therefore, while the expansion lasts, some motive force must have generated the work represented by the moving of the sleeve upwards. This motive power is derived from the excess of actual centrifugal force due to the speed V_a over the ascending velocity of equilibrium w. The result is that the velocity of equilibrium of the governor (w) must, under these conditions, be smaller than that of the engine, and Ω_2, the greatest velocity of equilibrium of the governor, must consequently be made smaller than the final speed $V_a = 62·84$ revolutions. *Fig. 3* gives a clear explanation of the position.

Here the ascending and descending velocities of equilibrium of the governor are traced in thick lines, and marked with arrows. These diagrams of v and w are almost rectilinear, and are supposed to belong to a governor which has been rendered astatic by the method explained in the Author's former Paper. The mean velocity chosen is equal to the geometric mean between the extreme speeds ω_1 and Ω_2. If we take one of these, $\Omega_2 = 62$ revolutions, and $\omega = 61·21$ revolutions, the other may be found as follows:—

$61·21 \times 61·21 = 62 \times \omega_1$, from whence $\omega_1 = 60·43$ revolutions.

As to the diagrams of velocities V_a and V_b, *Fig. 3*, they are

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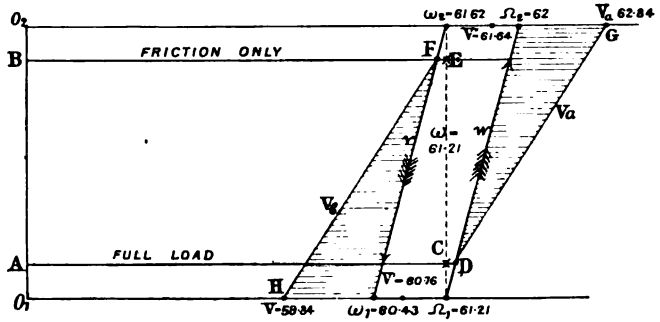
suppositions. The extreme points alone, D and G for V_a, and F and H for V_b can be determined with certainty, if the sleeve has been able to reach the end of its travel during expansion; for the law of variation of the velocity V_a is known as a function of the position of the crank, but not of the position of the sleeve. It will simplify this explanation if the accuracy of the diagrams V_a and V_b be admitted.

The sleeve of the governor being at the height A, the engine runs first at the normal speed represented by the length AC; the governor will move and ascend as soon as the velocity equals the value of w_0 = AD = 6·317 feet per second, corresponding to 61·31 revolutions. It is seen by the position of the point X on the diagram of V_a in *Fig. 2*, that the governor will begin to rise

Fig. 3.



between points 12 and 13, when the crank has described a curve of 0·938 foot from the beginning of the back stroke.[1] The sleeve will then rise, and ought at latest to have reached its highest position when the piston has arrived at the end of the stroke. The time the piston takes to pass from the position X to the end of the stroke may be calculated, the mean speed of the crank-pin traversing the distance of 2·154 feet in this time being given. This mean is 6·433 feet, and the time occupied 0·335 second.

In the second case here treated, the sleeve of the governor is at the height B, *Fig. 3*, the engine is running empty at its normal speed 61·21 revolutions, and with almost perfect regularity. At

[1] It may be objected that the governor will move during the ordinary working of the engine, since the fly-wheel allows a velocity of 6·353 feet. But the same reasoning would hold good if we suppose the loaded engine to be running at a mean velocity inferior to its normal speed of 61·21 revolutions.

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the beginning of expansion, during the back stroke, the load is suddenly thrown on, and the speed diminishes rapidly, as shown by V_0 in *Fig. 2*. The sleeve begins to fall as soon as the speed has become equal to BF, *Fig. 3*, which occurs towards the beginning of expansion. The mean speed of the centre of the crank-pin is 6·215 feet, and the duration of expansion 0·366 second. The speed at the end of the stroke is 6·117 feet, corresponding to 59·34 revolutions.

For reasons given above, the governor ought, therefore, to be so adjusted that, if the first case happens, the sleeve, acted upon by the excess of actual centrifugal force over that which establishes the equilibrium, should, starting from the height A, reach the highest part of its travel in less than 0·335 second. Should the second case occur, the sleeve, starting from the height B, ought to have reached the lowest end of its travel in less than 0·366 second, influenced by the lack of centrifugal force, which has decreased below that establishing the equilibrium. To choose the tachometer and calculate its mass and dimensions in accordance with these conditions is a matter of great difficulty. The Author proposes the problem, and is of opinion that the arithmetical part of it may be approximately solved by simplifying it with appropriate hypotheses. He thinks that regulators with springs alone might be sufficiently quick. It would be interesting, though laborious, to study the slow action of ordinary governors.

Finally, let it be supposed that in the first case the governor has suppressed the admission from the end of the stroke considered. Henceforth at each stroke the fly-wheel will lose 1,205·1 foot-lbs. in power, but as it possesses an excess of $\frac{3621}{2}\{V_a^2 \text{ final} - V^2 \text{ mean}\}$ = 3,888 foot-lbs. it is only after $\frac{3888}{1205 \cdot 1} = 3 \cdot 2$ strokes that it will be reduced to the mean velocity, and that the sleeve will fall a little, in order to furnish 1,205·1 foot-lbs. of work per stroke. This operation will doubtless cause it to oscillate slightly. It is of course desirable that the sleeve should fall as soon as the mean velocity of 61·21 revolutions has been re-established, and therefore it is well to make the maximum descending velocity of the sleeve, or ω_2, equal to the average velocity. In *Figs. 1* and *3* the Author has assumed that this takes place.

Similar considerations apply to the second case and its consequences. Here, however, the increase of motive power per revolution, which is needed to restore the normal speed, starting from 59·34 revolutions, is arbitrary. If, for example, the normal

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conditions are to be restored after two revolutions, an increase of work equal to $\frac{3621}{2 \times 2} \{V^2 \text{ mean} - V_1^2 \text{ final}\} = 2 + 62 \cdot 4$ foot-lbs., must be exacted per revolution, or 15 per cent. of the work required under normal conditions, and with the maximum load.

If a governor has been so calculated that it fulfils the extreme conditions here defined, it will bring back the velocity to the normal rate whenever it deviates from it, and will keep it within the assigned limits, whatever may be the load thrown upon the engine, if this load does not exceed the fixed maximum limits. But the momentum of the fly-wheel must also be calculated, that it may powerfully assist the governor, should urgent need arise.

The communication is accompanied by a diagram and two sketches in the text, from which *Figs. 1–3* have been prepared.

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(*Paper No. 2517.*)

"Investigations on the Influence of Heat on the Strength of Iron." [1]

Report of Professor Martens.

Translated and abstracted by GEORGE RUDOLPH BODMER, Assoc. M. Inst. C.E.

IN the year 1886 two technical societies, the "Verein zur Befoerderung des Gewerbfleisses," of Berlin, and the "Verein Deutscher Eisenhuettenleute," of Dusseldorf, proposed to carry out experiments on the influence of heat on the strength of steel (*Flusseisen*) of various grades of hardness. A commission, representing both societies, was appointed to agree upon the plan of operations, and consisted of the following members:—

On the part of the "Verein fuer Gewerbfleiss":—Privy-councillor Dr. Wedding, president; Mr. Hoppe, machine manufacturer, of Berlin; Professor Ludewig, Berlin; Mr. Martens, engineer, Berlin.

On the part of the "Verein Deutscher Eisenhuettenleute":—Mr. Brauns, Dortmund; Mr. Massenez, Hœrde; Mr. Minssen, Essen; and, after the death of the last-named, Mr. Asthofer, also of Essen.

In the original the Author states at length the reasons which led the "Verein fuer Befoerderung des Gewerbfleisses" to act in concert with the other society for the purpose of instituting the investigations in question. It was considered that previous experiments had not been sufficiently uniform and exhaustive, especially with iron and steel up to a temperature of 600° Centigrade.

The commission decided on the following points as a basis for the conduct of the experiments:—

1. The method of producing the material shall be left to the ironworks; but the latter shall be requested to report as accurately as possible on the nature of the process adopted, as well as upon

[1] Mittheilungen aus den Koeniglichen technischen Versuchsanstalten zu Berlin, 1890, p. 159.

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all details important for judging of the material, and of its particular condition.

2. The material to be tested shall be mild steel, and must be grouped according to its strength. Four groups are to be formed, corresponding to the stress-intervals 22·86, 26·67, 30·48, and 34·28 tons per square inch (in annealed condition). The first group to be of the quality of rivet-steel.

3. If at all practicable, only carbon is to be used for determining the grade of hardness; the other constituents must be as far as possible subordinate, and present, at least approximately, in equal quantities.

4. The material for each of the previously-mentioned groups is, as far as possible, to be taken from a single bloom, but in any case from a single heat. The individual pieces are to be rolled into round bars of about 1·5 inch diameter, the same proportion of stretch and the same temperature being employed for all.

5. From each of the four groups at least 229 feet 8 inches of round bars in all will be necessary, which are to be furnished in parts, the length of which must be a multiple of 3·15 inches.

6. The test-pieces are to be again annealed in the Berlin Experimental Institute by some uniform process before the commencement of the experiments.

I. The Test-Material.

Thirty-four bars of 1·5 inch diameter were furnished by the Hoerder Bergwerks- und Huettenverein of Hoerde, formed out of two charges, having a strength of 22·86 and 26·67 tons per square inch.

From each charge three blooms were used, and the bars so marked that it could be recognized to which bloom they belonged.

The Union-Aktien-Gesellschaft für Bergbau, Eisen- und Stahlindustrie, of Dortmund, furnished twenty-one bars of 1·5 inch, derived from two charges, but not so marked that their origin could be recognized.

As to the method of manufacture, it was agreed between the two works that the bars should be forged from 9·84 inches square blooms down to a section of 4·32 inches square, freed from the rough ends, and then rolled to a diameter of 1·5 inch in lengths of 26 feet 2·97 inches to 32 feet 9·71 inches.

In order to neutralize as far as possible the effect of inaccuracies on subsequent comparisons, the test-pieces cut from each length

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were consecutively numbered and selected for testing in the corresponding order.

For the purpose of annealing, the rough test-pieces were packed in lots of seventeen or eighteen in cast-iron muffles, the covers of which were coated with clay, the muffles having been previously charged with a cake of clay furnished with strips of lead, tin, zinc, and aluminium. Each muffle held two layers of bars, one above the other, and two muffles were always placed side by side in the annealing furnace. Through the roof of the latter a graphite pyrometer was inserted in such a manner that its lower end was between the two muffles.

A detailed record of each annealing was made, and in the original an example of one of these records is given. In most cases it could be seen after annealing that the aluminium had been softened.

Test-pieces of similar quality were tested as they arrived from the manufacturers, and also after annealing. The results of these tests are stated in a tabular form in the original.

The material furnished for Group IV, which should have had a tensile strength of 34·28 tons per square inch, was found not to conform with the required standard, and was in the first instance excluded from the investigations.

II. The Experiments.

A. Arrangements.

The testing of the unannealed normal test-pieces was carried out in the manner usual at the Experimental Institute. For the tests at higher temperatures, however, the form of test-piece shown in *Fig. 1* was finally adopted. On the conical shoulder of

Fig. 1.

Form of Test-piece.

the test-piece the heating furnace was supported, the arrangement being as follows:—

The test-piece was placed in a vessel, having a clear width of about 4 inches, which could be filled (up to 200°) with paraffin, or (up to 600°) with molten metal.[1] This vessel was surrounded by

[1] Either alloys of lead and tin or lead only. Previous experiments had shown that lead was not absorbed by the steel within the time required for a test.

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an iron jacket into which the flames of two gas-jets could be introduced through lateral slots. The escape of the fire-gases could be controlled by means of a slide. The burners were connected to the frame of the 50,000-kilogram testing-machine, and carried through the water-main. Each flame was 4·32 inches wide.

The test-piece and furnace together were supported in the machine from the heads of the piece by means of spherical socket-bearings in the well-known way. The size of the flames could be regulated by altering the supply of gas and air to the jets. The temperature of the bath of molten metal or paraffin was determined up to 400° by the help of a mercurial thermometer filled with nitrogen, by Geissler, of Bonn, and at higher temperatures by an air-thermometer with iron air-vessel, the construction and regulation of which was at first attended with many difficulties.

The tests, in a cold condition at −20° Centigrade, were carried out in a zinc vessel with double walls, which was also secured to the cone of the test-piece. The inner, as well as the outer vessel, after several unsuccessful preliminary trials, was filled with a powdered mixture of ice and salt. In this way a temperature very near −20° Centigrade could be maintained for a considerable time. The outer vessel was surrounded with a jacket of asbestos and a layer of sawdust. The load was measured either by means of weights placed on the attachment on the right-hand side of the testing-machine, or through the automatic mechanism on the left-hand of the machine. A description will be found in the "Zeitschrift des Vereins deutscher Ingenieure," 1886, p. 171, and "Mittheilungen aus den Technischen Versuchsanstalten," 1889, Supplementary number III.

The measurement of the elastic extensions could not be carried out with the ordinary mirror apparatus; but a special arrangement had to be designed with the object of placing the mirrors beyond the influence of the stream of hot air rising from the furnace, since an accurate reading with mirrors is only possible in air of uniform density. The elastic extension of the actual test-length (a cylindrical portion 8·1 inches long, and 0·79 inch diameter) could not be directly measured. In order to protect the knife-edges for the mirrors as much as possible from the effects of the heat, both measuring rods were fixed with their knife-edges in a groove turned in the lower part of the test-piece, and wedged fast by means of a ring pushed over them. The knife-edges of the mirror-apparatus were then adjusted between the measuring-rod and the test-piece in the existing marks above the furnace.

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The elongations of the test-length could also not be directly observed. Instead of this, the total motion of the piston of the machine was determined, either by means of the existing scale for the stroke, or by measuring the abscissae obtained from the automatic recorder.

The drum of the latter is actuated from the piston of the machine through a fine wire, while the pencil follows the motions of the quicksilver gauge, and thus describes a curve on the paper attached to the drum. The elongations, as well as the elastic alterations of form, had, of course, to be reduced to the test-length, as will be subsequently explained.

The previously-mentioned scale for measuring the stroke of the piston is chiefly for the purpose of controlling the velocity of flow during the experiment. In order to facilitate this, the rod connected with the piston actuates, in addition to the pointer for the scale, a roller, the indicator of which shows the stroke of the piston exaggerated fourteen-fold. It is a general rule in the Berlin Experimental Institute so to regulate the piston-speed that during the flow of the test-piece the test-length is increased by 1 per cent. of its original length in a minute.

This velocity was to be maintained as far as practicable during the experiments in question.

B. Method of conducting Tests.

In ordinary tests, with the machine employed for these experiments, no measurements are taken between the moment when the maximum load is reached and the final fracture. In the present case, however, it was thought desirable to observe more accurately the phenomena occurring between maximum load and fracture, since it was evident beforehand that at different temperatures very considerable differences in the behaviour of the metal during this period would show themselves.

For observing the decreasing tensile strength of a test-piece the automatic recorder on the left side of the testing machine was employed. The course of an experiment was generally as follows: The test-piece, after accurate measurement of all parts, was pushed from below into the furnace, and a tight joint, made by means of the conical shoulder smeared with fine clay; the test-piece and furnace were then firmly connected by a nut. The iron tube, filled with nitrogen, of the air-thermometer, was next placed inside the furnace, the measuring-rods of the mirror

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apparatus were attached, and finally the stirring mechanism and cover.

After the test-piece had been fixed in the spherical bearings of the testing-machine, the mirror apparatus was connected. The adjustment of the measuring-rods and mirrors required great care, and in the original this adjustment is described in detail.

Before commencing observations it was found necessary to allow the test-piece and measuring-rods, which had become heated by contact with the hand, to cool for from ten to fifteen minutes. All the pieces to be tested at high temperatures were previously tested several times at an ordinary temperature as to their elastic extension within the limits of proportionality, so that the extension for one ton [1] could be determined with great accuracy, and from this the modulus of elasticity. After these preliminary observations, the gas-jet was lighted and the furnace gradually heated. The material for filling the inner space of the furnace was melted and poured into the latter when sufficiently hot. The temperature up to 400° Centigrade was observed with a mercurial thermometer at higher temperatures with an air-thermometer. At 450° the results obtained from the two thermometers were compared and graphically recorded. A curve of a definite form corresponded with the readings of the air-thermometer, but the curve varied on different days, so that a group of curves embraced within certain limits was obtained, the range of which can be seen from the following table :—

Mercurial Thermometer.	Air-Thermometer.	
Centigrade.	From	To
Degrees.	Millimetres.	Millimetres.
100	158	170
200	255	280
300	335	365
400	395	430
500	445	485
600	485	525

For experiments under 500° comparative readings were taken from the mercurial and air-thermometers, in order to determine the curve corresponding most closely with the records of the latter

[1] The ton used throughout this Paper is the metric "tonne," = 0·9842 ton avoirdupois.

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on the day in question. In this manner it was sought to neutralize the variations of the air-thermometers.

The two mercurial thermometers used were calibrated before the experiments at 0°, 100°, and 187° (aniline vapour), and found correct. During the course of the experiments they were frequently (together with the air-thermometers) placed in boiling water, and it was found that gradually they indicated the boiling point 11° too high. The results obtained were corrected for this, but for various reasons the records cannot be considered as accurately representing the temperature actually existing in the bath. Since, however, the same instruments were employed throughout, the experiments are directly comparable with each other and relatively correct. The constancy of the mirror readings could be approximately maintained by stirring the bath.

The stirring mechanism consisted of a ring of sheet-iron, which could be moved up and down by means of a rod with curved handle. This, however, only affected the lower portion of the bath, and in future experiments some improvement on this device would be desirable.

When the metal bath was made use of in the experiments considerable oscillations occurred in the diagrams, so that frequently the readings could only be correctly taken within fifteen to twenty or sometimes even thirty ten-thousandths of a millimetre. Attempts to get rid of these oscillations were unsuccessful, and their origin could not be discovered with certainty. It is not improbable that they were due to the action of cooler currents of air on those portions of the test-pieces and measuring-rods projecting out of the bath.

In general the mirror apparatus was employed up to the moment when flow commenced, and then the test-piece was relieved, the mirrors removed, and the experiment repeated and continued till fracture with the automatic recorder in use.

The experiments at − 20° were carried out in a similar manner. In the first experiments the test-piece was surrounded with a saline solution, having its freezing-point at exactly − 20°. If the outer mixture was at first too cold, it was intended that the inner solution should commence to deposit crystals, and that when towards the close of the experiment the temperature outside rose, the previously formed crystals should dissolve again; in either case the temperature would remain constant.

The mixture in the cooling vessel, with a capacity of 29·933 pints, consisted of three parts by weight of ice and one part of salt.

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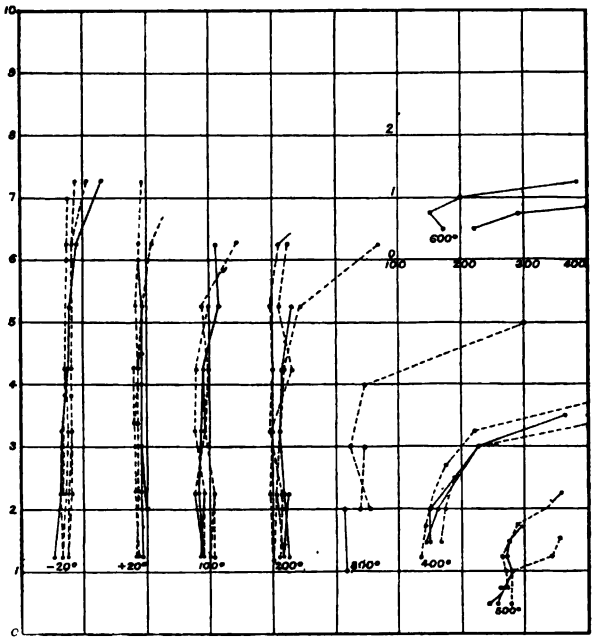
The temperature in the outer space of the cooling vessel was thus maintained throughout the whole experiment, which had a maximum duration of four hours, between − 20° and − 21°. It was, however, found impossible to reduce the temperature of the saline solution in the inner space below − 17°. For this reason the inner vessel was also eventually filled with a freezing mixture, with satisfactory results. Observations taken at various points of the inner space always showed temperatures between − 20° and − 21°. Other observations were carried out as previously described.

Fig. 2.



QUALITY I.—EXTENSION-DIFFERENCES FOR VARIOUS LOADS.

Scale of abscissæ, 8 millimetres = 0·001 millimetre extension-difference.

The time necessary for bringing the test-piece to the required temperature before each experiment was utilized in trying the recording instruments.

Up to the moment at which flow commenced, the hydraulic valve was only very slightly opened, in order to give the apparatus time to follow the rapidly changing stress. Subsequently the extension took place at a speed of one per cent. in the minute. The form of the diagram immediately after the commencement of flow

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Fig. 2.

QUALITY II.—EXTENSION-DIFFERENCES FOR VARIOUS LOADS.
Scale of abscisse, 8 millimetres = 0·001 millimetre extension-difference.

Fig. 3.

QUALITY III.—EXTENSION-DIFFERENCES FOR VARIOUS LOADS.
Scale o abscisse, 8 millimetres = 0·001 millimetre extension-difference.

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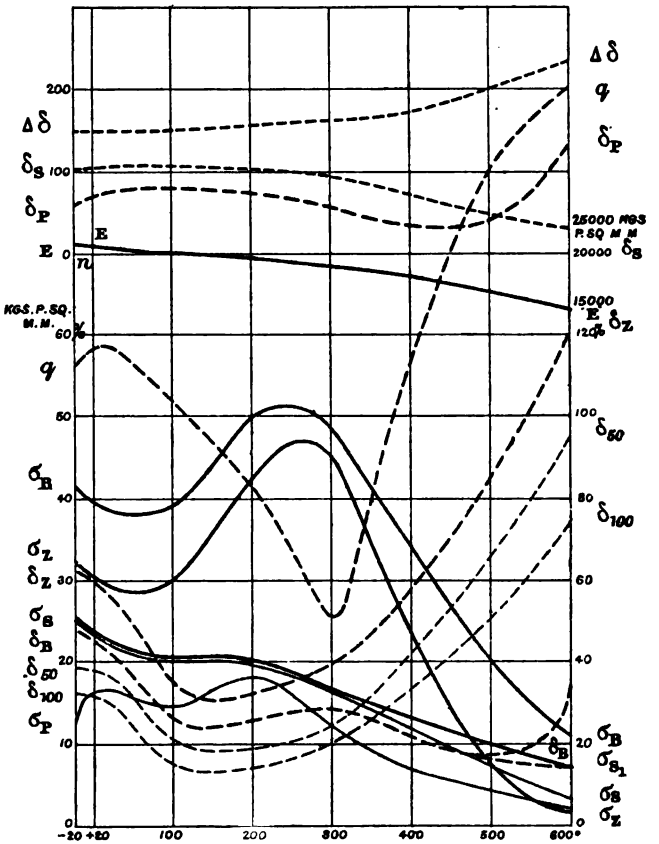
depends very materially on whether the valve is opened instantaneously and to what extent, and is therefore more or less dependent on the attention and will of the observer.

C. Calculation of Results.

Under this heading in the original the various formulas employed in determining the required quantities from observed readings and data are given.

Fig. 3.



QUALITY I.

III. RESULTS OF EXPERIMENTS.

The main results are given in a tabular form in the original, but for convenient comparison are also graphically represented.

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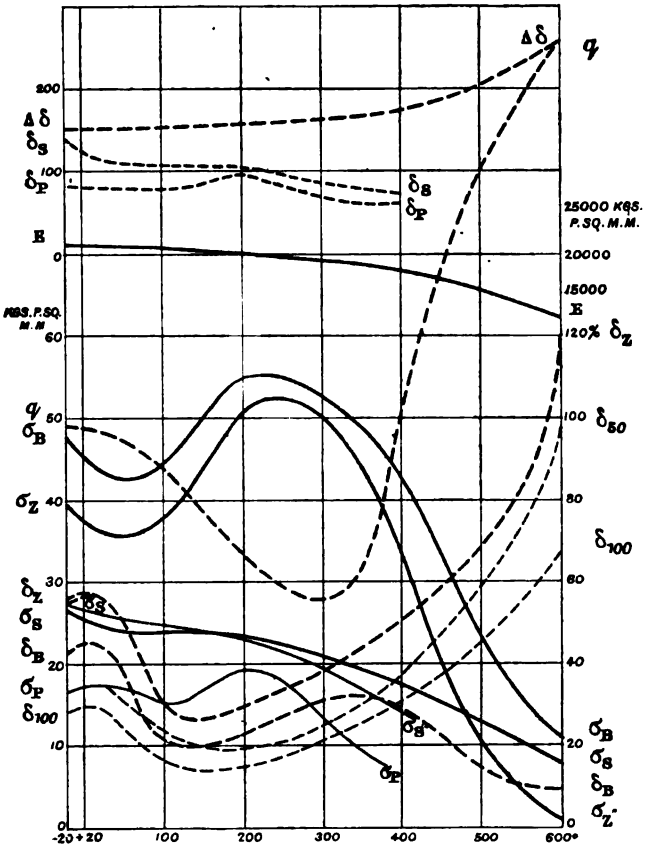
In *Figs. 2* the extension differences, corresponding to the various loads, are shown for different qualities of metal (I, II, and III) and various temperatures. These diagrams allow an opinion to be formed of the degree of accuracy obtained, and also on the question as to how far the material can be credited with a proportional extension. From the decreasing length of the parallel portions of the curve-groups with increasing temperatures, the lowering of

Fig. 4.



QUALITY II.

the limit of proportionality is plainly visible. Even at 300° it appears questionable whether the test-pieces can be truly said to show any proportional extension.

In *Figs. 3*, *4*, and *5* the chief results are delineated for the three qualities of material, respectively I, II, and III.

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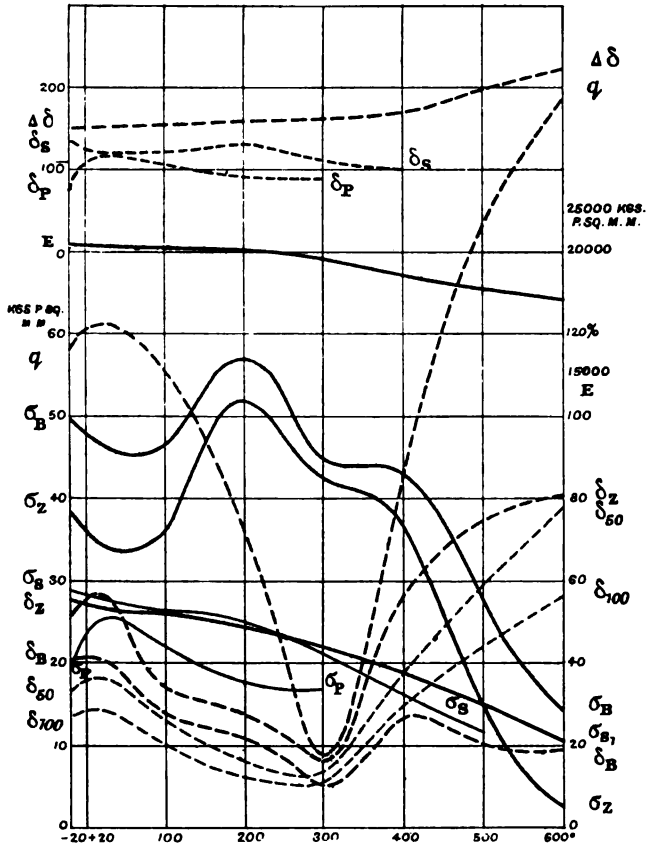
The quantity represented by each curve is denoted by the

Fig. 5.



Quality III.

letters at the commencement of each on the left hand, the meaning of the notation being as follows:—

Δδ Percentage of elongation per ton of load.

δ_s Percentage of elongation at the limit of stretch (*Streckgrenze*).[1]

δ_p " " " proportionality (*Proportionalitaetsgrenze*).[2]

E Modulus of elasticity.

[1] The "limit of stretch" is what is popularly termed the "limit of elasticity," and, more correctly, "yielding-point," where flow of the metal commences.

[2] The "limit of proportionality" is the point up to which stress and strain, accurately measured, remain proportional.

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q Contraction of area in per cent.
σ_B Maximum stress.
σ_Z Breaking stress.
δ_Z Percentage of elongation at fracture.
σ_S Stress at limit of stretch.
δ_B Percentage of elongation at maximum load.
σ_P Stress at limit of proportionality.
δ_{100} Percentage of elongation in 200 millimetres.

the elongations, except where otherwise stated, are referred to the test-length of 206 millimetres.

Figs. 3 to *5* show very clearly how the stresses σ_B and σ_Z decrease considerably from − 20° up to about 50°, and after that rapidly increase until they attain a maximum at from 200° to 250°. This maximum value is for all the qualities of material tested considerably in excess of the value for + 20°, and by the following amounts :—

Quality. (Grade of Hardness.)	Excess for σ_B	Excess for σ_Z
	Per Cent.	Per Cent.
I	34	62
II	27	45
III	25	50

The curves for σ_Z follow a similar course. On comparing the curves for σ_B and σ_Z it will be found that the maxima and minima occur at nearly the same temperatures. The following are the ratios of σ_Z to σ_B in per cent. for various temperatures, as calculated from the mean values obtained :—

Quality of Material.	Ratio for							
	− 20°	+ 20°	100°	200°	300°	400°	500°	600°
I . .	76	75	77	86	96	66	39	12
II . .	85	82	85	92	96	76	43	7
III . .	7	74	79	91	96	84	49	16

With the exception of some of the test-pieces (of quality III), supplied by the Union Company, the material which is strongest in a cool state remains so when heated.

The diagrams, *Figs. 6* and *7*, allow a comparison of the leading results for all three qualities of material tested. Qualities

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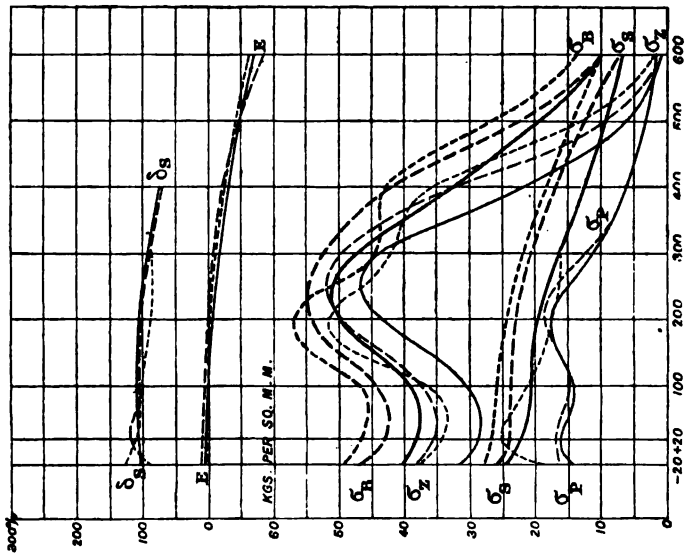
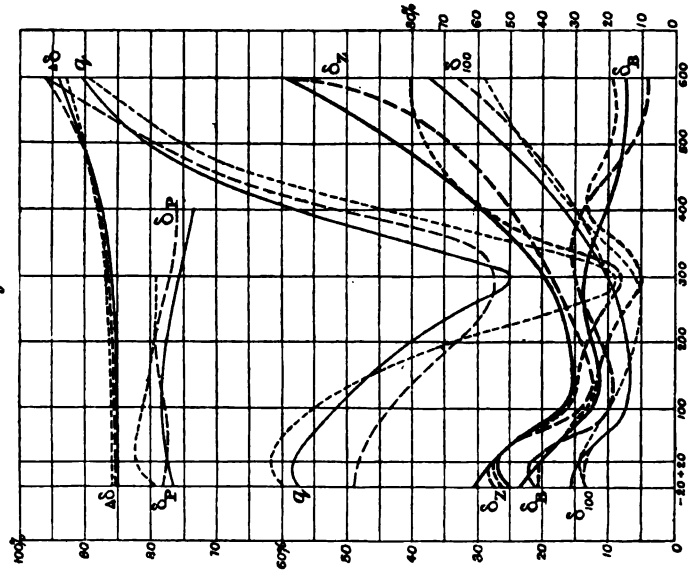
Fig. 6.



LEADING RESULTS FOR QUALITIES I—III.

Fig. 7.



LEADING RESULTS FOR QUALITIES I—III.

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I and II were supplied by the Hoerde Company, quality III by the Union Company.

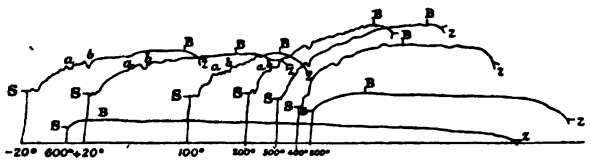
In general the last of these (III) exhibits the same characteristics in regard to the values of σ_n and σ_z as the other two, but deviates noticeably from the latter at 300°. The elongation δ_n increases between − 20° and + 20°, and then, for the "Hoerde" material, decreases and reaches a minimum at about 130°. From this point the curves rise again up to between 280° to 330° and then fall. For the "Union" material (III) the minimum value of δ_n is attained only at 300°, and the curve afterwards rises, a maximum occurring at 400°. Similar differences are also to be observed in the character of the curves for δ_z.

The following Table, compiled from the mean observed values, gives the ratios in per cent. of δ_n to δ_z for various temperatures:—

Quality of Material.	Ratio for							
	− 20°	+ 20°	100°	200°	300°	400°	500°	600°
I . .	78	76	76	79	73	36	20	[28]
II . .	75	79	68	76	81	58	19	8
III . .	78	72	81	74	59	48	26	15

In *Fig. 8* the stress diagrams for material of quality II are reproduced. The limit of stretch, in each diagram, is denoted by

Fig. 8.



Stress Diagrams for Quality II and Temperatures − 20° to 600°.

S, the point of maximum stress by B, the point of fracture by Z. At 400° the material has assumed the character of the soft metals, zinc for instance. The irregularities at the points *a* and *b* occurred when the flow extended to the shoulders of the test-piece, beyond the actual test-length.

The variations in the contraction of area are extraordinarily great. For all three qualities of material the smallest value of *q*, the reduction of area, occurs at 300°.

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The stress at the limit of proportionality increases with rising temperature between $-20°$ and $+20°$, reaching a maximum about $+20°$, it then falls slightly to 100°, and at 200° attains a second higher maximum, subsequently falling rapidly. The elongation at the limit of proportionality δ, is subject to no appreciable alterations. For the stresses usual at ordinary temperatures the engineer may therefore reckon, in steel heated even up to 200°, on elongations proportional to the load and on sufficient safety. It would, however, scarcely be safe to draw conclusions from the results of these experiments as to the admissible working stress for temperatures over 200°, or for frequent changes of temperature ranging from 150° to 350°. Reliable values in such cases could only be arrived at by repeated tests, continued for long periods (*Dauerversuche*), with the metal in a heated state.

The question of the safety of iron structures may be influenced by the peculiar behaviour of the material at 300°. At this temperature the strength is greater, but the reduction of area and elongation less than in a cold state. Fracture occurs suddenly without previous contraction, the metal exhibiting a certain brittleness, which also finds expression in the appearance of the fractured surface. On this account it is questionable whether at 300° steel is capable of resisting repeated shocks.

The original is accompanied by facsimiles of photographs of the test-pieces after fracture, arranged in groups according to the temperatures at which they were tested. From these a tendency is evident for the fracture to occur at a particular part of the piece for each temperature. This is probably due to want of uniformity in the heating of the piece, causing it to yield in the coldest or hottest part, according to the effect of heat at the different temperatures.

At each temperature the character of the fracture has also a distinctive form.

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(*Paper No. 2527.*)

"Authorities on the Steam-Jacket: Facts and Current Opinions."

By Professor R. H. THURSTON.[1]

Abstracted by BRYAN DONKIN, Jun., M. Inst. C.E.

IN this Paper the Author summarizes the opinions entertained, and experimental data furnished by leading scientific engineers respecting the use and advantages of the steam-jacket. He begins by quoting a phrase of Mr. G. A. Hirn, "that the effects of the steam-jacket have been alternately vaunted and denied, but the public have never yet been put in possession of the actual facts." Such, even at the present day, is for the most part the state of knowledge upon the subject.

Knowing the differences of opinion which exist as to the value of the steam-jacket, and its relative efficiency under different circumstances in ordinary practice, it has been deemed desirable to examine and summarize the views of some of those who have studied the subject. Much uncertainty still prevails as to the effect of the jacket, and it is an open question whether it is of any practical utility at all. Under these circumstances there can be no better method of clearing up doubtful points than that here adopted by the Author. To bring together the opinions of so many authorities must lead to a certain unanimity of judgment, and this, as will be seen, is in favour of retaining the jacket as a means of increasing the economy and efficiency of the steam-engine. A correct theory, when it is obtained, will show that the jacket may be either a decided advantage, an unimportant appendage, or have a deleterious effect upon the working of the steam-engine.

The Author does not here profess to give his own views on the subject of the steam-jacket. They had been already laid before the public in a paper on "The Philosophy of the Multiple-Cylinder

[1] The original Paper was presented to the American Society of Mechanical Engineers in November 1890.

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Engine," presented to the American Society of Mechanical Engineers, November 1889. In it he says that steam-jacketing is a common partial remedy for waste, and may be made to produce the effect of superheating, that is, to secure drier steam in the engine. High-speed engines derive less advantage from it than those of low-speed ones, and the economy is not so marked in compound as in single-cylinder engines. The saving effected is about 20 per cent., and a similar gain may be obtained by superheating. In compound engines the Author considered it advisable to jacket the whole series of cylinders, since "to omit the jacket from any increases the aggregate loss of heat in the whole engine." The greater the piston-speeds, the less the necessity for the jacket, and it is not unfrequently omitted from marine engines, which attain a speed of 1,000 feet a minute, while slow-moving pumping engines must be jacketed to work economically. The actual numerical value of the economy obtained by the jacket can only be determined by collating the numerous experiments made by independent observers.

The steam-jacket was invented by James Watt, and patented in 1769. His attention was drawn to the waste of heat in the engines he had already made, which he attributed to the introduction of the steam into a chilled cylinder, and he laid down the obvious principle, still valid after 120 years, that it is necessary to keep the cylinder always as hot as the steam which enters it. This he proposed to do either by covering it with a non-conducting material, or by surrounding it with a heated body, such as steam. From that day to this, therefore, the steam-jacket has been more or less a necessary adjunct of economical engines. The phenomenon of cylinder-condensation was certainly known to Watt. Although he does not appear to have fully understood the theory of the steam-jacket, he always employed it, for he found that when he tried to lay it aside, the consumption of fuel was much greater. It was only in later years that its use was discontinued by engineers who did not understand that the type of engine, and the quality of the steam, often diminished, and sometimes wholly annulled, the advantage of the steam-jacket.

The first of modern writers to draw attention to Watt's jacket was Combes. In the Comptes Rendus of the French Académie des Sciences, 1843, he says that the object of the jacket is to maintain the temperature of the steam, and to prevent condensation during expansion, and that it gave an economy of about 36 per cent. In 1844 Mr. Gill found that even where the steam is dry, and no loss by radiation takes place, a loss of heat

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caused by the sudden evaporation of the steam, in other words, cylinder-condensation ensues. This theory was verified by Mr. Farcot, a French engineer, who, as early as 1848, built compound engines with both cylinders jacketed.

But the honour of establishing the theory of the steam-jacket on a firm experimental basis unquestionably belongs to Hirn. He introduced a new method of gauging the heat of an engine, and his researches materially contributed to the elucidation of the subject. In every trial he measured the quantity of water entering the boiler and there turned into steam, the quantity of steam in the cylinder, and the heat transferred to the metal from the steam, and returned to the steam too late to transform it into mechanical energy. He found that the economy produced by the steam-jacket was 23½ per cent. This was obtained not by actual diminution of the quantity of fuel and steam consumed, but by augmenting the amount of work done by the engine. From this he deduced the principle that the influence of the steam-jacket consisted in preventing the partial condensation of the steam during expansion, and the resulting loss of pressure. The quantity of heat consumed by the engine must alone be taken as the true measure of its efficiency. If the theoretical value of the engine be calculated without reckoning the waste found in actual practice an error of 30 to 60 per cent. may arise, and this will be increased if the waste produced by heat taken up by the exhaust-steam be neglected. Hirn found that the walls of a single-cylinder engine give up the same amount of heat to the steam with as without a jacket, but in the former case the heat is yielded during expansion, costs nothing, and adds to the work done, while without a jacket this heat is passed into the condenser without doing any work, because it evaporates the condensed water after the exhaust-valve has opened. This has been confirmed by subsequent experiments. But whatever the result obtained with compound engines, the value of the jacket with single-cylinder engines is incontestible. Hirn's able coadjutor Hallauer considered that this type of engine can with the aid of the jacket be made as efficient as the compound. But both Hallauer and Hirn thought that the advantages gained by superheating the steam were still greater than those of a jacket. With a compound engine a gain of 20 per cent. was obtained by using superheated steam to 410° Fahrenheit; with a single-cylinder engine with steam superheated to 437° Fahrenheit, an economy of 31 per cent.; and when the temperature of the steam was raised to 473° Fahrenheit a gain of 47 per

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cent. was noted. Superheating gives an advantage to a single cylinder over a compound Woolf engine of nearly 14½ per cent., both working without a jacket.

Superheating, however, has not found much favour with engineers because of the wear and tear to the engine. John Penn appears to be the only authority who recommended it; he was of the opinion that to superheat the steam before it enters the cylinder is preferable to the use of a steam-jacket, and believed it to be possible in large marine engines thus to secure dry steam throughout the stroke.

As early as 1858 Professor Rankine recognized that the principal effect of the jacket invented by Watt is "to prevent the liquefaction of steam in the cylinder." This condensation, however, he attributed only to the quantity of steam condensed during the expansion in the preceding stroke, which was very small. Still he thought it possible, by the use of a jacket or superheated steam, greatly to diminish the loss of efficiency arising from the conducting-power of the cylinder. He deprecated the absence of a jacket, and declared that the practice of marine engineers proved that it was useless, if not wasteful, to employ the high rates of expansion suited to compound engines, if the jacket were abandoned. The use of the steam-jacket was also advocated by Mr. Cowper, Mr. L. E. Fletcher, and by Mr. Labouchère. The latter considered that the economy resulting from it ranged from 20 to 25 per cent. In a series of experiments reported to the "Vereine deutscher Ingenieure" by Mr. Hirn, it was found that a condensing non-jacketed engine, when expanding ten times, demanded 74 per cent. in excess of the theoretical quantity of steam required; when cut off at one-fifth 62 per cent.; and with three expansions 55 per cent. excess. The addition of a jacket reduced these losses to 64, 54, and 48 per cent. respectively. Increased piston-speed produced the same effect as a jacket; an engine running at a speed of 3 feet per second showed a loss of 96 per cent., with 7 feet speed the loss was 70 per cent.

The first of later writers to describe the way in which heat is wasted in an engine is Mr. D. K. Clark. Writing in 1850 he maintained that to prevent condensation in steam worked expansively, the cylinder must be kept at the initial temperature of the steam. Even with a steam-jacket, however, this condensation is not wholly avoided; the use of superheated steam was probably more effectual. In a single-cylinder engine he considered the gain with a jacket was about 15 per cent., and from 10 to 12 per cent. in the compound engine. The advantage obtained with a

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jacket in the single-cylinder engine is due to the fact that the range of pressure and temperature is more in it than in each separate cylinder of the compound engine, between which it is distributed. Another advantage was obtained by having long-stroke cylinders, on account of the proportionally larger surface of the covers and pistons exposed to the action of the steam in short-stroke cylinders.

These opinions were confirmed by Mr. Isherwood. His experiments showed that the steam-jacket is of real advantage, but varied in the degree of economy it confers. Where no expansion is used, and the cylinder is large, there is practically no gain. The greater the expansion and initial pressure, and the less the speed, the higher the efficiency with the jacket, but where condensation is prevented by superheating, it has no effect. Small engines give an economy of 20, and large of 8 or 9 per cent., but the steam used in the jacket must be brought direct from the boiler.

Ledieu does not wholly endorse these views. He thinks the steam-jacket should be applied to all the cylinders of a compound engine, and that with compounding, superheating and a jacket, it might sometimes be possible to attain an economy of 40 per cent., but special care must be bestowed on the construction of the jacketed cylinder. It is not advisable to make the cylinder and jacket in one piece throughout, nor to allow the boiler steam to pass from the jacket into the cylinder, since it has already been cooled. The ordinary economy of a steam-jacket he fixes at 15 to 25 per cent. unless the heat in the jacket is insufficient to prevent cylinder-waste, when it becomes harmful instead of beneficial.

The effect of the jacket upon the quantity of fuel used was shown in experiments by Messrs. Farey and Donkin. In a compound engine the fuel per indicated HP. per hour was 2·6 lbs. with, and 3·8 lbs. without, jackets; and in another, the water rate per indicated HP. per hour was 24¼ lbs. with, and 39½ lbs. without, the jackets. In a marine compound engine built by Messrs. Napier, the number of revolutions fell from 63 to 58 per minute when the jackets were shut off.

Turnbull thinks the steam-jacket more effectual and economical when applied to compound than to single-cylinder engines, on account of the greater range of temperature in the latter, while Professor Trowbridge says the gain is greater if the large cylinder of a compound engine be jacketed than if a jacket be applied to the cylinder of a single engine. Mr. Emery fixes the saving at

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11·78 per cent. in the latter example, and in the former at 11·72 per cent., and his opinion of the value of the jacket is confirmed by Mr. G. Holmes. Mr. Cornut, the French engineer, puts the gain at from 15 to 20 per cent., and he found that shutting off the jackets produced a sensible reduction of initial pressure. Professor Cotterill enunciates the useful rule that great caution is necessary in drawing conclusions from any special set of experiments on the influence of the steam-jacket. Its employment is strenuously defended by Mr. R. Sennett.

Longridge gives an instance in which on an economical compound engine he obtained slightly better results without than with jackets.

Loss from leakage appears to be one of the objections to their use, even where it is admitted that the jackets prevent condensation during admission, and reduce waste. This difficulty, however, can be overcome. The economy obtained with the jacket appears to be especially marked when it is applied to Woolf engines with two cylinders, though Mr. Lee, an American engineer deprecates its use.

A series of valuable experiments were made by Mr. Delafond at Creusot in 1883 upon a Corliss engine. It was found that the greatest economy was obtained with the jacket at equal ratios of expansion with higher steam-pressures, while the less the expansion with equal pressure, the less the economy due to the jacket. A gain of 15 to 20 per cent. was reported in these experiments. The proportion existing between expansion and the economy due to the jacket was clearly exhibited in Mr. Borodin's valuable series of trials, where the gain was 12 per cent. with 3½ expansions, and 16 per cent. with about five expansions. In one case the gain to the engine was 14 per cent. owing to a decrease of 8 per cent. in initial condensation; but notwithstanding these figures, Mr. Borodin was not on the whole favourable to the employment of steam-jackets for locomotive engines, unless they are properly constructed and thoroughly drained. He found that a jacket was in some cases positively injurious, and was always of less value with a compound than a single-cylinder engine. Owing to defective handling, the gain attested when the engine was under cover was lost when on the road.

Messrs. Crampton, Walker, and Wylie all consider the steam-jacket of advantage, and the latter thinks it essential to attain maximum efficiency. From motives of economy it is frequently discarded; and there is no doubt that cylinder-waste takes place

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in spite of the jacket, especially in the high-pressure cylinder of a compound engine. Professor Ewing thinks the jacket useful with slow-running engines when well drained, increasing their efficiency 20 to 25 per cent., but of small benefit in high-speed engines. In a single-cylinder pumping-engine running at 20 revolutions per minute, Mr. Mair-Rumley reported that the steam used was 22 lbs. per I.HP. per hour with a jacket, and 26½ lbs. without. In the latter case the cylinder-condensation was from 25 to 37 per cent. more. Professor Dyer, when reviewing Mr. Willans' experiments, pointed out that the use of the steam-jacket was no longer so imperative as formerly, since the steam was maintained at a more even temperature by the successive cylinders of a compound engine. The ideal function of a jacket was simply, he considered, to prevent condensation, but unfortunately it also acted as a boiler. In the compound engine it generated steam in the low-pressure cylinder, which, instead of doing work, passed immediately to the condenser; and it was better this steam should be sent on in the form of water. The sub-division of expansion into successive steps economized the steam better. The use of a steam-jacket also violated a fundamental law of heat-engines, namely, that they should receive their heat at the maximum, and give it out at the minimum temperature, instead of at an intermediate temperature. Professor Dyer is, however, willing to allow that a steam-jacket is of advantage where the ratio of expansion is large; but he thinks super-heating a better method of reducing waste.

Professor Schröter, of Munich, gives particulars of a set of experiments conducted by him on a triple-condensing Sulzer engine, jacketed throughout. The boiler-pressure was 150 lbs., ratio of expansion 24, and the quantity of steam per I.HP. per hour 15·2 lbs. Remarkable results were also obtained by Professor Reynolds[1] at the Whitworth Laboratory, Manchester, with three independent cylinders combined in a triple-engine. In this very economical engine the loss by shutting off the jackets was about 18 per cent.

Professor Dwelshauvers-Dery, of Liége, subjected these figures to analysis, and found that the cylinder-jackets afforded a net gain of 17 per cent., due to their action in promoting efficiency of working, apart from the thermodynamic efficiency. The famous experiments of Hirn showed, according to Mr. Dwelshauvers-Dery, a gain of 25 per cent. caused by super-heating; but to super-heat the steam of a cylinder already jacketed did not, he

[1] Minutes of Proceedings Inst. C.E., vol. xcix. p. 152.

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thought, add to any appreciable extent to its efficiency. Such were also the views entertained by Hirn himself, who, only a few weeks before his death, declared that "the use of super-heated steam absolutely dispenses with the need of a jacket." A manufacturer of Roubaix, however, found that with super-heated steam in the jacket the speed was increased nearly 10 per cent.

Mr. Mallet, a French engineer, says that the utility of the jacket is so much the more as the difference of temperature is greater between the walls of the cylinder and the initial steam. He thinks the jacket most advantageous on a single-cylinder engine, while Professor Unwin would apply it in all cases and to all cylinders, provided ordinary steam be used; "but the advantages may diminish to an amount not worth the interest on extra cost."

Two American engineers, Worthington and Edwin Reynolds, advocate the use of the jacket. In some of Mr. Reynolds's experiments on a compound engine at 12 revolutions per minute he obtained an economy of 33 per cent. with jackets. Driving the engine up to 56 revolutions, the gain fell to 9 per cent. Pumping engines, when tested, showed a decided saving with the jackets; and Mr. Reynolds's experience leads him to conclude that a marked advantage is obtained where the larger cylinder is jacketed with boiler-steam over jacketing with steam of lower pressure. Two or three manufacturing firms, among them the Westinghouse Co., think the economy obtained with the jacket hardly compensates for the cost of construction. Mr. Leavitt considers the jacket advantageous for every kind of cylinder. Mr. Hill concurs, if proper conditions be maintained, and summarizes his views as follows:—

1. The steam-jacket is best adapted to low speeds and high expansive-engines.

2. For high pressures, with wide range of expansion and temperature, it is desirable to have a jacket.

3. The higher the ratio of expansion, the greater need for the jacket.

4. With super-heated steam it is comparatively valueless.

5. With compound or triple-engines the high-pressure cylinder, if little expansion be used, should not be jacketed.

Professor Schröter deduces the following conclusions from his experiments:—

1. The value of the jacket may vary within wide limits, or become negative.

2. The shorter the cut-off, the greater the gain with a jacket.

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3. The use of higher pressure in the jacket than in the cylinder is of advantage. The greater the difference the better.

4. The high-pressure cylinder may be left unjacketed without much loss; the others should always be jacketed.

The following Table (pp. 234–237) gives a list of the experiments cited by Professor Thurston.

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STEAM-JACKET EXPERIMENTS

Number.	Type of Engine.	Dimensions.						Pressure of Steam.	Ratio of Expansion.
		Diameters.			Strokes of				
		First Cylinder.	Second Cylinder.	Third Cylinder.	First Cylinder.	Second Cylinder.	Third Cylinder.		
		Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Lbs.	
I.	Single-cylinder.	..	..	..	..	..	..	..	..
II.	Non-condensing.	2	..	..	8	..	..	115	..
III.	,,	$7\frac{5}{16}$	..	..	$26\frac{1}{8}$	..	..	45	1–2·7
IV.	,,	..	..	..	..	..	..	..	8 and 21
V.	,,	..	..	..	..	..	..	..	10
VI.	,,	34·1	..	..	30	..	..	68·5	3·5–4·4
VII.	,,	16·54	..	..	23·62	..	..	50–78	3·3–5·4
VIII.	,,	21·65	..	..	43·31	..	..	50–110	1–7·1
IX.	Single-cylinder.	..	..	..	..	..	..	53	6
X.	Condensing.	15·35	..	..	31·5	..	..	50–58	20
XI.	,,	5·25	..	..	10	..	..	38–56	5·3
XII.	,,	90	..	..	117	..	..	12	1·7
XIII.	,,	70	..	..	110	..	..	36	4
XIV.	,,	$7\frac{5}{16}$	..	..	$26\frac{1}{8}$	..	..	45	1·8
XV.	,,	$20\frac{1}{16}$	..	..	$41\frac{3}{4}$	..	..	80	10
XVI.	,,	26	..	..	30	..	..	17	3·4
XVII.	,,	25	..	..	24	..	..	78	$5\frac{1}{4}$
XVIII.	,,	34·1	..	..	30	..	..	13–71	1·5–7·8
XIX.	,,	24	..	..	48	..	..	67–68	5·7–12·4
XX.	,,	30	..	..	42	..	..	30–60	3·1–4·7
XXI.	,,	39·37	..	..	70·87	..	..	60–62	13–15
XXII.	,,	32	..	..	66	..	..	42	3·8–4·3
XXIII.	,,	21·65	..	..	43·31	..	..	36–110	1–14

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QUOTED BY PROFESSOR THURSTON.

I.HP.	Revolutions per Minute.	Gain per cent. due to Jackets.	Authority.	Date.	Parts Jacketed.	Type of Engine, &c.
120	..	8–10	Thomas & Laurens.	1846	..	..
..	203	23	McKay.	1859	..	..
4·5–10·6	45–51	11–21·5	Donkin.	1874	Body and bottom end jacketed only.	Beam-engine.
79–136	..	13·8–19·5	Cornut.	1874	..	..
..	..	19	,,	1874	..	..
170–212	46·7–53·2	10·3	Loring and Emery.	1875	Body and both ends jacketed.	Steamship 'Gallotin.'
40–59	92–102	7¼–22·4	Borodine.	1881–83	..	Locomotive; summary of twelve experiments.
108–237	60–64	1·0–22	Delafond.	1883	Body only jacketed.	Summary of twenty-two experiments.
..	..	30–32	Thomas & Laurens.	1842	..	..
6–7	..	27·5–41·7	Combes.	1843	..	..
0·93–1·13	60–61	31·2	Isherwood.	1860	Body, both ends and valve-chest jacketed.	..
352–361	7·9–8·1	2·7	,,	1860	Body only jacketed.	Pumping-engine.
153–161	12	12·9	Donkin.	1870	Body only jacketed.	Pumping-engine.
7·7–9·3	37–40	19·4	,,	1870	Body and bottom end jacketed.	Beam-engine.
56–83	55	23·7	Hirn.	1873	..	Beam-engine.
39–42	37–40	31·3–32·4	Rennie.	1873	..	Beam-engine.
89–116	47–54	11·8	Emery.	1874	..	Steamship 'Bache.'
87–348	40–69	6·1–16·3	,,	1874	Body and both ends jacketed.	Steamship 'Gallotin.'
81–158	49–50½	21·5–30·3	W. Meunier.	1878	Body and both ends jacketed.	..
170–192	58	15·5	Fletcher.	1877	Body and both ends jacketed.	..
166–174	27	17·1	Farcot.	1879	Body only jacketed.	Pumping-engine.
124	20½	16·6	Mair.	1882	Body and bottom end jacketed.	Pumping-engine.
69–212	58–62	½–26·6	Delafond.	1883	Body only jacketed.	Summary of forty-six experiments.

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STEAM-JACKET EXPERIMENTS

Number.	Type of Engine.	Dimensions.						Pressure of Steam.	Ratio of Expansion.
		Diameters.			Strokes of				
		First Cylinder.	Second Cylinder.	Third Cylinder.	First Cylinder.	Second Cylinder.	Third Cylinder.		
		Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Lbs.	
XXIV.	Compound.	16⅛	29 1/32	..	49⅛	66⅜	..	56	4·3
XXV.	Condensing.	7 1/16	14	..	26⅛	36	..	41	5·5
XXVI.	,,	13 3/16	24	..	39⅛	54	..	41	11–14
XXVIa.	,,	13 3/16	24	..	39⅛	54	..	41	12
XXVII.	,,	7 1/16	14	..	26⅛	36	..	45	10·3
XXVIII.	,,	20 3/16	31¼	..	51⅛	70⅞	..	60	13
XXIX.	,,	16	25	..	24	24	..	80	7
XXX.	,,	6	10	..	12	12	..	42	4·45–10·78
XXX.	,,	6	10	..	12	12	..	42	5·38–16
XXX.	,,	6	10	..	12	12	..	42	5–13
XXXI.	,,	22	34	..	43	66	..	45	9½–16
XXXII.	,,	24½	38	..	41	66	..	73	7·8–9·6
XXXIII.	,,	19	25	..	24	24	..	80	7
XXXIV.	,,	6	10	..	12	12	..	40–96	8–11
XXXV.	Triple-condensing.	5	8	12	10	10	15	190	15–26

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QUOTED BY PROFESSOR THURSTON.—*continued.*

I.HP.	Revolutions per Minute.	Gain per cent. due to Jackets.	Authority.	Date.	Parts Jacketed.	Type of Engine, &c.
Brake HP. 78–102	23½	23½	Hirn.	1855	Body and bottom jacketed.	Beam-engine.
17–20	36	28·6	Donkin.	1859	Body and bottom ends jacketed.	,,
28–46	32½	31·2	,,	1868	Body and bottom ends jacketed.	,,
37	32½	13·7	,,	1868	Only 4 lbs. pressure steam in jackets.	,,
10–17	37–44	38·6	,,	1870	Body and bottom ends jacketed.	,,
119	25	4·5	Lhoest.	1873	Low-pressure cylinder only jacketed.	,,
77–99	48–53	11·7	Emery.	1874	..	Steamship 'Bache.'
6·7–10·5	98	25·5	Donkin.	1881	Bodies only jacketed; steam in h.p. jacket only.	Horizontal engine.
7–12	98	29	,,	1881	Bodies only jacketed; steam in l.p. jacket only.	,,
7–13	98	34	,,	1881	Bodies only jacketed; steam in both jackets.	,,
75½	18–19½	35	Mair.	1881	Bodies and both ends jacketed.	Pumping-engine.
268	34	8·7	,,	1881	Bodies only jacketed.	..
157–168	55	15·4	Donkin and Kennedy.	1887	Bodies only jacketed.	Pumping-engine.
7–13	75–101	4·4–38·2	Kennedy.	1888	..	Summary of twenty-one experiments.
73	280–322	17–18	Reynolds.	1890	Jacketing very complete.	Vertical-engine.

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(*Paper No. 2503.*)

"On the Sewerage and Sewage Disposal Works of the Borough of Dudley."

By EDWARD DIMMACK MARTEN, M.A., Assoc. M. Inst. C.E.

THE difficulty of dealing with the sewage of the populous district which overlies the celebrated South Staffordshire ten-yard seam is enhanced by mining-operations. Wherever this coal is worked the surface is more or less affected, and subsides or is "drawn," sometimes gradually, but sometimes with such suddenness as to endanger life. Water-pipes of the ordinary description are frequently fractured by these movements, which often cause considerable leakage at the joints. So much is this the case that the Author's father, Mr. Henry John Marten, M. Inst. C.E., many years ago found it necessary to design a special socket to obviate the difficulty. Some of the canals which intersect the district are now carried upon embankments, 20 feet in height, over ground which, within the memory of man, was on a level with their banks. It will readily be understood that these subsidences, which are of every-day occurrence in the Black Country, seriously interfere with the work of the sanitary engineer.

The difficulties are not so formidable in the towns themselves as in the districts which surround them, since in most cases the value of the surface-rights in towns, and the necessity of affording vertical and lateral supports to buildings, make any mining operations thereunder impracticable, and it is generally, but not always, found possible to construct and work a system of internal sewerage. It is mainly in connection with outfall and intercepting sewers laid outside town limits that the troubles accruing from mining-operations are experienced.

Whilst, moreover, the mining in this district is a standing cause of leaky sewers, it is at the same time emphatically a reason why they should be watertight. The South Staffordshire Mines Drainage Commissioners have spent large sums of money in draining the coalfield and in constructing works to prevent water finding its way into the mines, and they very properly watch with

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a jealous eye any action which may possibly add to their pumping-expenses. All sewers constructed outside the actual town district have to be laid in a thick bed of puddled clay, and sometimes are required also to be of cast-iron.

Sewage-farming within the mining-area would be attended with great difficulty, as even if a sufficiency of surface land could be acquired without the vast expense of purchasing the minerals below, anything in the shape of irrigation would be open to suspicion, as likely to send water into the mines, and would probably be opposed by the Mines Drainage authorities on that ground. Precipitation, aided by artificial filtration, is practically the only process available for the central towns of this district, unless the sewage can be conveyed by some means over the intervening mining ground on to the non-mining *terra firma* which surrounds it. Precipitation, however, is also attended with considerable difficulties, because to enable the necessary works to be constructed, the first requirement is suitable land, the mines and minerals underlying which must be purchased. This adds considerably to the cost, and further difficulties are often experienced on account of the operations of adjoining mine-owners, which have a tendency to "draw" the site and the structures erected upon it.

The municipal borough of Dudley has a population of about 46,000, the town itself containing about 30,000 inhabitants, while the remaining 16,000 are scattered among the mining villages which lie within the borough boundaries. It is situated upon a ridge running nearly north and south, and forming a portion of the watershed of England, the natural drainage of the town being partly into the Severn basin, and partly into the Trent basin. Some of the houses stand at an elevation of over 800 feet above sea-level; and the lowest part of the ridge, where it passes through the town, is 660 feet above sea-level. The districts to be drained lie on each side of the main hill, extending as far down as 590 feet above sea-level, so that it is only possible to deal with the whole sewage of the town at any one point, by means of long lines of intercepting sewers connected by a tunnel about ½ mile in length through the ridge. To these difficulties, arising from the conformation of the ground on which the town is built, were added those arising from mining-operations around it.

In 1876 the Corporation purchased an estate known as the Russell's Hall estate, 70 acres in extent, closely adjoining the western side of the town, and lying at a sufficiently low level to deal with the whole of the sewage from both sides of the ridge.

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It was proposed to bring the sewage to this land by means of intercepting sewers traversing both flanks of the hill upon which the town is built, and connected by a tunnel, and to deal with it there by means of a combination of filter-beds and irrigation. The estate consisted entirely of mining-ground, and the scheme was consequently opposed, both by the South Staffordshire Mines Drainage Commissioners, and by the late Earl of Dudley, who was by far the largest ratepayer in the borough, and who was advised that the diversion, as proposed by the Corporation, of storm-water as well as sewage on the land, would injuriously affect his mines in the neighbourhood, and the streams passing through his estates, besides being unnecessarily costly and likely to create a nuisance. Mr. H. J. Marten was consulted, and with the concurrence of Mr. George Taylor, the agent for the surface of the Dudley and Himley estates, prepared an alternative scheme which was laid before the Town Council in a Report, on July 25, 1876. This scheme, after a delay occasioned by the necessity of obtaining an Act of Parliament—certain portions of the Earl's settled estates being affected by the covenants entered into with the Corporation —was carried out by Mr. H. J. Marten, assisted by the Author, during a period extending from June 25, 1879, to July 30, 1884.

The town has been entirely re-sewered on the separate system, and upon the most modern principles. The gradients are in most cases so steep that practically no artificial flushing is required, and from the same cause a few ventilators carried up the sides of the houses in the higher parts of the town are sufficient, with the aid of the ventilating covers of the manholes, to keep the sewers free from noxious gases. The branch sewers are all stoneware, and the joints are made with tarred yarn and cement. Manholes are placed at every change of line or gradient. Only one case of stoppage has occurred since the system has been in operation; and on an investigation being made as to the cause, it was discovered that a butcher was in the habit of discharging hot fat into the sewer. This was put a stop to, and it has always worked well since. The houses have, to a large extent, been disconnected from the old drains, which are intended to be used henceforth exclusively for surface-water, which they convey to the streams and brooks, eleven in number, forming the natural outlets from the town. Only such storm-water as it is impossible to exclude is allowed to enter the new sewers. The old drains, as is usually the case, were found to be of immense size compared with the work they were constructed to perform, and to have

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been put in without any attempt at system, and the capital outlay which they represent would probably, if properly applied, have sufficed to put down three or four complete modern systems of internal sewerage for the town.

The sewage, collected as above described, gravitates to an intercepting-sewer along each side of the ridge upon which the town is built. These intercepting-sewers, whose flattest gradient is 5 feet per mile, converge upon the Russell's Hall Estate, the northern one being for the last ½ mile in a tunnel which is in some places more than 100 feet below the surface of the ground. The hill through which this tunnel passes has been formed by an upheaval of the Upper Silurian Limestones, which here form an anticlinal, from the summit of which the coal measures have been denuded. No trouble, consequently, was experienced from mining operations in driving the tunnel, though the intercepting-sewers themselves suffered greatly from this cause. They had to be laid almost entirely in a thick bed of puddled clay, and as near the surface of the ground as possible, which added seriously to their length, as it was necessary to follow the contour of the land. To show the difficulties which have to be contended with in a mining country, the Author may mention that during the construction of the works, he found one morning that some 30 yards of the new sewer had disappeared bodily into the workings below, leaving nothing to be seen except a deep hole resembling the crater of a volcano. This accident rendered necessary a somewhat costly deviation from the line originally selected.

At Russell's Hall Estate, the liquid is first sent through rough strainers formed of broken blast-furnace cinders, and capable of removing the heavier solid matters; it is then passed into a small reservoir or storm-water catch-pound, formed partly by excavation and partly by embankment, and capable of holding about 2,500,000 gallons. This storm-water catch-pound is situated upon the upper part of the Russell's Hall Estate, and the level of its top water-line is 544 feet above Ordnance Datum. There is a considerable fall between this and the River Smestow, 4½ miles to the westward, the bed of which is 344 feet lower. Still going westward, the country rises rapidly for the next mile beyond the river to the summit of a range known as the Black Hills, which is 426 feet above Ordnance Datum. From this point there is a gradual fall westward for some miles. The sewage, collected as above described into the storm-water catch-pound, is delivered by gravitation through a 13-inch cast-iron main, acting as an "inverted siphon," across the valley of the River Smestow, on to the summit of the

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Black Hills above referred to, near the Whitehouse Farm, in the centre of a considerable area of land belonging to the Earl of Dudley. This 13-inch main is 5½ miles in length, and the *average* fall between the catch-pound and the point of delivery at Whitehouse Farm is about 21½ feet per mile. It will be observed from the plan and section, *Figs. 1* and 2, p. 243, that the pipe follows all the irregularities of the land along which it is laid, with rising gradients in the steeper parts, ranging from 1 in 10 to 1 in 21, the total rise from the bottom of the valley to the Whitehouse Farm being 210 feet in a length of ¾ mile.

There is an overflow weir at the top-water level in the catch-pound, but the Author is informed that the accumulated sewage has never risen so high, even during storms. In ordinary times it passes directly from the sewers into the 13-inch main without rising up in the catch-pound, and although consequently it undergoes no previous "settling," and the only treatment it receives is from the rough strainers above referred to, the scouring power is such that the main is always free from silt. Indeed, when first the works were put into operation, large stones and other débris left in the pipes during the construction were forced through the main by the current and discharged at Black Hills, although in some parts the gradients up which they were rolled were as steep as 1 in 10½ to 1 in 8½.

Means are provided at all depressions of scouring out any deposits which may form, and air-valves are fixed at every summit. In constructing these, care was taken to prevent the possibility of the ball-seats becoming at any time choked with sewage. This was effected by means of a separate connecting-pipe between the bottom of the ball-seat and the main air-valve branch. In all other respects the fittings were the same as for an ordinary water-main. For the first 2½ miles the 13-inch main traverses the mining district to the west of Dudley, but near Himley Hall, one of the seats of the Earl of Dudley, the main fault is crossed, and for the remaining 3 miles of its course it is entirely over the Soft Red Rocks and Conglomerates of the Bunter Series of the New Red Sandstone, which also extend beyond it for 2 miles to the west of the terminus, and for many miles to the north and south.

Throughout the last 3 miles, the main lies entirely upon the property of the Earl of Dudley. It is provided, at convenient intervals, with lateral branches leading to circular brick reception-tanks placed in elevated situations on various parts of the estate. On each of these a sluice-cock is fixed so that sewage may be

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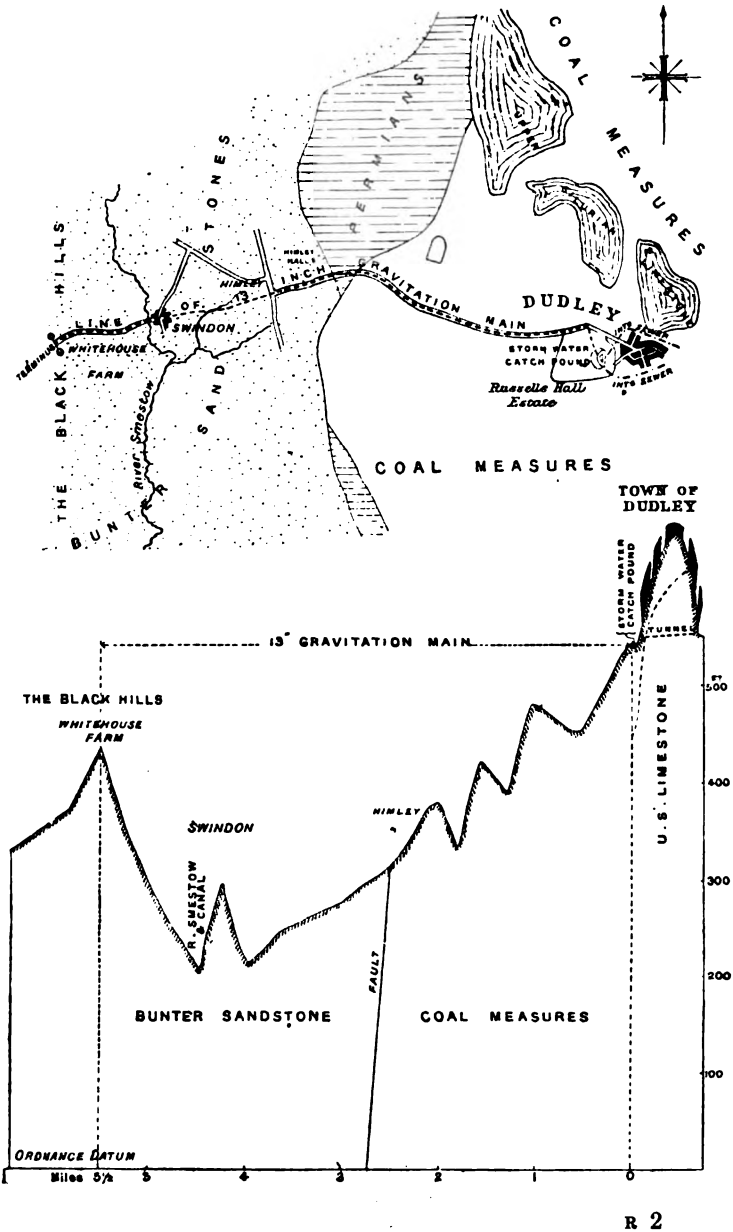
Figs. 1 and 2.



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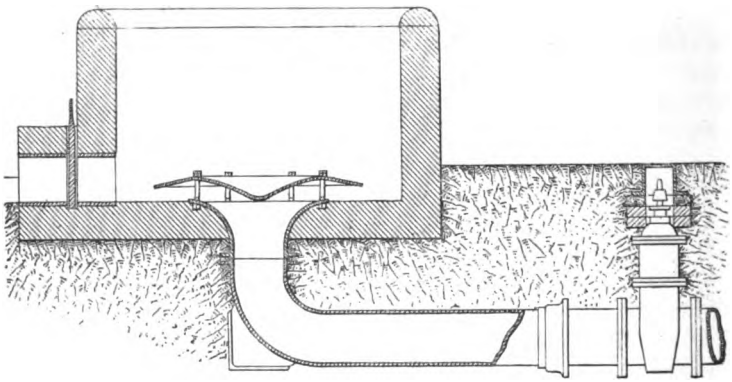
run into the tank when desired. In order that it may not be discharged high into the air by the pressure in the main, a wrought-iron shield or spreader is fixed over the inflow, so that the liquid impinges against it, and is spread quietly over the floor of the reception-well. Openings leading in several directions and guarded by sluice-boards are provided in the tank, and through these the sewage passes to carriers in any direction (*Fig. 3*). This ramification of distributing-pipes is available over a tract of country (including certain lands to the west of the terminus at the Black Hills) some 4 or 5 miles in length, and having an average breadth of 2 miles, or between 5,000 and 6,000 acres in area.

Although this land is available, and is amply provided with

Fig. 3.



Scale ¼-inch = 1 foot.

SECTION SHOWING THE SPREADER IN THE DISTRIBUTING WELL.

the means for the distribution of the sewage, by far the larger proportion of it serves for the present merely as a reserve, and the most interesting operations are to be observed on a comparatively small area in the neighbourhood of the terminus at Black Hills. Here the sewage is applied intermittently to three farms, with an aggregate of 722 acres, under the control of the Earl of Dudley's principal land agent, Mr. George Taylor. Unlike the greater part of the available land (which is upon the Upper Soft Red Rocks of the Bunter Series, and which is tolerably fertile), these three farms are upon the Conglomerate, and the soil is poor and sandy, so that prior to the construction of the works of

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the Dudley Corporation this land was a bye-word in the neighbourhood for sterility. At first the supply of sewage, as might naturally have been expected, was limited; but as from year to year it has increased, the fertility of the farms has developed in a more than corresponding degree. So much is this the case that the Earl (whose leading condition on offering the Corporation the facilities they enjoy, was that he should be entitled to the whole of the sewage from the town) is now threatening legal proceedings against them for their alleged neglect to compel the householders to connect with the new system.

This bargain is perhaps unique in the history of sewage disposal. The Earl of Dudley takes the sewage from the Corporation without either paying for it or receiving any payment for doing so. He relieves the Corporation, by an ample indemnity, of all further responsibility in connection with it, by an agreement which has been ratified by special Act of Parliament. Thus the town of Dudley is rid for ever and entirely of its "sewage question," whilst that portion of the Earl's estates under treatment is considerably improving in value. The bargain has been satisfactory to both the parties to it.

A point upon which sanitary engineers will desire information is as to the nature of the effluent from these farms. Mr. Taylor, on being asked, replied, "We have never seen an effluent. The soil absorbs it all," and it is impossible to detect, either in the River Smestow or any other neighbouring brook course, a trace of the proximity of sewage-farming operations. The district is sparsely inhabited, but it has never been suggested that there is any contamination of the few local wells.

Although it could not be expected that a system such as this should have been in operation for the past six or seven years without occasional allegations that a nuisance was being created, it has generally been possible to show the complainant wherein his error lay. On one occasion an excellent imitation of the ideal sewage smell was produced in the village of Swindon, which is adjacent to the land under treatment, by the practice of cooling the ashes from a small local ironworks by pouring water upon them. It was not until this practice was discontinued—when the smell at once ceased—that the inhabitants were satisfied upon the point. It is now generally conceded that the sewage works, whilst greatly enhancing the prosperity of the agricultural community, produce no more nuisance than the manuring of land usual in rural districts.

No precipitation is required. The matter held in suspension,

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which has been described as the bane of the ordinary sewage-farmer, and which clogs the pores of ordinary soil, is found, when applied in the intermittent and sparing manner adopted in this case, to mix admirably with the sandy soil, the nature of which it is gradually changing. The essential feature of the scheme is that the land available is practically of unlimited area as compared with the volume of the sewage. Finally, there are no working expenses. The Corporation men clean out the strainers at Russell's Hall once a week, and by way of precaution a turn-cock is sent along the line of the 13-inch main once a month to open and oil every valve. In every other respect the system is self-acting.

The total cost of the works, including the internal sewers, the intercepting-sewers, the storm-water catch-pound, and the 5½ miles of 13-inch gravitation main, was about £44,000, but the purchase of Russell's Hall estate, way-leaves for intercepting-sewers, and other extraneous expenses, brought the total up to about £55,000. The cost of the 13-inch main and the necessary valves for scouring purposes, &c. (but exclusive of the distributing fittings), was 16*s.* 2*d.* per yard, laid complete. No way-leave had to be paid. The storm-water catch-pound, with the necessary ironwork, brickwork, &c., cost 16*s.* 1½*d.* per 1,000 gallons capacity, or, including a high unclimbable iron fence which was ultimately found to be necessary, 17*s.* 11*d.* per 1,000 gallons. The intercepting and internal sewers, including all man-holes, junctions and other necessary adjuncts, but exclusive of way-leaves, cost £30,422 5*s.* 3*d.*, or £1 0*s.* 3*d.* per head of the population served by the sewers. The above figures are based on the final certificates. They do not include engineering or clerk of works, for which, and one or two other small matters, about 7½ per cent. should be added.

In connection with the question of way-leaves, a somewhat curious case arose. Lord Dudley, in his original agreement, gave a way-leave for the 5½ miles of 13-inch cast-iron outfall pipe to the Black Hills, but none for intercepting or other sewers. During the progress of the works it became necessary to carry the intercepting-sewers through his lordship's land, which for more than a mile was mining ground, and his trustees were advised that they had no option but to press for full compensation. The matter was referred to an arbitrator, and it was contended, on behalf of Lord Dudley's trustees, that under the Public Health Act, 1875, the Corporation must acquire and pay for the minerals necessary to afford vertical and lateral support to the sewer; that

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to afford such vertical and lateral support considerable areas would require to be left unworked, which would vary in width according to the depth and inclination of the strata, but which in some cases might be as much as 80 yards wide, and that in the then existing state of the law, the way-leave for the construction of the sewers would deprive his lordship's trustees of the right to get minerals over a large area of land, for which they claimed as compensation upwards of £22,800. This claim created great consternation, not only on account of its magnitude, but because it was to a certain extent a new one and was sure to become a test case, and if upheld the Corporation would probably have to face a total outlay for compensation for way-leave of upwards of £50,000. The arbitrator awarded a surface value of £1,011, and submitted certain alternatives dealing with the mining question for the decision of the Court, which could only, even if given against them, entail a further expenditure of £3,000 upon the Corporation. The state of the law upon the question, however, was found to be so involved and unsatisfactory, that an amendment to the Public Health Act, 1875, was passed by Parliament in August, 1883 (46 & 47 Vict. chap. 37) giving public bodies the same facilities for taking sewers over mining ground as are enjoyed by railway companies.

In conclusion, it may be remarked that the Corporation of Dudley claim—and with some reason—that they have a sewerage system which is practically perfect. They enjoy all the advantages of the possession and user of a sewage-farm without any of its liabilities; they are burdened with no perpetual charge in the shape of working expenses; they have an entirely modern system of internal and outfall sewerage which gives complete satisfaction, and they get all this for the moderate expenditure upon works of under 30*s.* a head of the population. Moreover, the only other interest affected (that of the Earl of Dudley) has largely benefited by the operations. That Dudley has succeeded in wiping off what may be termed the adverse balance resulting from mining-difficulties, and from the physical conformation of the town, and in replacing it by the exceedingly substantial asset which has been described, should be an encouragement to municipalities where the sewage question is still unsolved. At the same time it must be admitted that this state of things resulted from three circumstances, all exceptional, namely:—

1st. That there was a practically unlimited tract of land eminently suited for the reception of sewage within a few miles of the town.

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2nd. That the level of this land was such as to allow of the sewage passing on to any part of it by gravitation.

3rd. That the owner was willing to take the sewage and deal with it thereon upon the terms which have been described.

The Paper is accompanied by drawings, from which the *Figs.* in the text have been prepared.

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(Paper No. 2513.)

"Petroleum-Storage Installations at Avonmouth and at Cardiff."

By R. PICKWELL, Assoc. M. Inst. C.E.

SCARCELY any industry in this country has grown with such remarkable rapidity as that of the import of petroleum. In 1859 it amounted to 2,000,000 gallons, and the official returns for 1889 show that in that year it exceeded 102,000,000 gallons. This enormous increase has called forth improved methods of conveying the oil and storing it. The old method of bringing it to England in barrels was successfully superseded about the year 1886, by the use of specially built steamers, provided with oil-tanks and powerful pumps. Owing to the presence in some cases of large proportions of naphtha, serious explosions have occurred, and legislative measures have been passed for the protection of the public. No oil that flashes at less than 73° on the Abel instrument is considered safe. Dr. (now Sir) Lyon Playfair, in evidence before a Parliamentary Committee, stated that he would not use oil that flashed under 120°, but would prefer 130°.

Although this substance was known to the ancients over 2,000 years ago, it has only within the last thirty years become an important article of commerce.

It is found over a wide field, including India, Persia, Peru, Java, the shores of the Caspian, the United States, Canada and South America. The chief supply at present is obtained from Pennsylvania and the Caspian Sea. The increase of the shipments from Russia is very remarkable; in 1883, 500 barrels were sent to this country, whilst in 1890 the supply was 787,529 barrels, or about 32,288,689 gallons per annum. During the same time the consignments from the United States increased from 53,000,000 gallons to 54,489,164 gallons per annum.

In this Paper it is proposed to give a description of two petroleum-storage installations, one erected at Avonmouth jointly by Mr. C. M. Jacobs, M. Inst. C.E., and the Author's firm; the other

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coming under his professional notice, both of which are provided with improved machinery and arrangements that may be of interest to the Institution.

Avonmouth Installation.

These works were erected for the Bristol, West of England, and South Wales Petroleum and Storage Association. In the storage of so inflammable and dangerous a commodity as petroleum great care is required in the selection of a site which shall afford facilities for easy communication with the steamers and vessels bringing the oil, and at the same time be as isolated from the neighbouring property as possible, in order to avoid such disastrous occurrences as the fires at Antwerp and Rouen. The site selected for these works (see Fig. 1, Plate 7) is situated on the banks of the Avon, about half a mile from the head of the Avonmouth Dock, being outside the ancient banks of the river, on what is known as the Outstays. It possesses on two sides deep water accommodation for barges or vessels, and on a third, railway connection with the main line from Avonmouth to Bristol. The site is leased from the Bristol Docks Corporation, and contains from 4 to 5 acres.

The first contract, which was let in July, 1889, was for the construction of a sea-bank, which was thrown up all round the site to a height of 6 or 7 feet, with the double object of shutting out the high spring-tides, and of confining the petroleum in case of the accidental bursting of a storage tank. As will be seen by the cross sections, Figs. 2, the banks generally were formed with a two to one batter on the river side, and a one and a half to one batter on the back, with a 4-foot top. The seat of the bank had the turf first pared off, and was then dug up one spade deep, after which the earthwork was barrowed up and put together by chopping and ramming in the usual way. After waiting for several months any settlement was made up, the batters trimmed off, and the bank sodded over. A cess-ditch was formed at the back of the outer bank for the purpose of drainage, and provided with a small outfall clough at A, Fig. 1, details of which are shown on Figs. 3, 4 and 5. The site was then thoroughly drained into the cess-ditch, by laying lines of 3-inch agricultural drain-pipes, 2 to 3 feet deep, every 30 feet, the trenches being filled with broken stone; and the whole of the surface was subsequently covered with ballast and ashes.

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At point B on the plan, a deep-water jetty was erected on the foreshore of the Avon, constructed of pitch-pine piles, ranging from 30 to 60 feet long, with timber walings, struttings, and deck, as shown in Figs. 6 and 7, where barges or vessels lie for either discharging or taking in cargo.

Tank Foundations.

The petroleum is stored in bulk in large circular iron tanks, two of which contain 2,000 tons each, and the others 1,000 tons each, and it was important that a firm foundation should be secured for them. Trial borings showed the ground to consist of about 6 feet of brown clay on the top, with 30 feet of very soft black warp below (Fig. 8). It was found that piling would be too expensive, and ultimately the Author designed the following plan, which was adopted.

After taking off the soil, a timber and concrete raft, about 5 feet larger in diameter than the tanks, was constructed; a layer of concrete, 18 inches thick, was first spread over the whole area, and upon this 12-inch by 6-inch timbers were laid across as shown, and another 18 inches of concrete put over the whole, thus forming a circular raft 3 feet thick and 68 feet in diameter for the large tanks, and 52 feet in diameter for the smaller ones (Fig. 14, Plate 7). These foundations have answered the purpose satisfactorily, and are similar to those used for the large grain warehouses at Avonmouth Dock. A gutter was formed all round the base of the tanks for collecting any leakage which might come from them. Sidings were laid from the main line of railway into the works as shown in Fig. 1, Plate 7.

The installation comprises three departments:—The storage tanks, the cooperage department, and the filling or barreling-off department.

It was desired to separate these as much as possible, keeping the tanks as well as the filling-house away from the cooperage and boiler-house to lessen the danger of fire. To maintain economical connection between these three departments, the installation is designed to work by the gravitation of both full and empty barrels from one department to another; for instance, the cooperage is connected with the filling-house by means of "barrel-runs," upon which the empty barrels, as they are turned out from the cooperage, run down to the filling-house and storing platform; empties also pass down similar runs from the jetty into the works for either storage or repairs; barrels already

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filled run from the filling-house down to the end of the jetty ready for shipment. The gradient used is 15 to 16 inches in 100 feet, which is found to be just sufficient to cause the barrels to move without any tendency to run away. The runs are carried on light trestles (see Figs. 9), and consist of timbers 5½ inches by 3 inches, fixed at about 2 feet 2 inches gauge by bolts. They are made in portable lengths of from 12 to 14 feet, and are put up where required. On reference to the general plan it will be seen that the cooperage floor is fixed at about 2 feet above the filling-house floor, and the filling-house floor a similar height above the jetty; the other runs have a similar gradient. The barrels are put on to them one after another, and close together, and as each one is taken off at the low end, the whole line moves forward one barrel. This method of dealing with them is important as regards the economical working of the installation.

Storage-Department.

A line of 6-inch wrought-iron screw-jointed filling-pipes is laid from the dock to the tanks along the surface of the ground, and is fixed upon strong wooden carriages to keep it in position. At the dock end is a stand-pipe similar to an ordinary water-main stand-pipe, or suitable bends are provided, which can be readily connected with a flexible hose-pipe from the steamer. At the other end of this main filling-pipe a branch with screw valves is taken off to each tank.

The tanks are circular and constructed of boiler-plates riveted together with lap-joints as in an ordinary gas-holder, the large ones being 64 feet in diameter and 30 feet high, the smaller ones 47 feet in diameter and 26 feet high. The bottom is made of $\frac{3}{8}$-inch plates, with 4 inches by 4 inches by ½-inch angle-irons. The sides are formed of seven tiers of plates of uniform width, the first and second being $\frac{5}{8}$ inch thick, the third and fourth $\frac{3}{8}$ inch thick, the fifth $\frac{5}{16}$ inch thick, and the sixth and seventh ¼ inch full. The tops are of ⅛-inch plates, supported on angle-iron frames and principals (Fig. 10). They rise 6 feet in the middle, forming a dome, and have four raised man-holes 24 inches in diameter, provided with hinged covers which can be locked. The attachment of the side and bottom plating to the angle-iron at the base is by a double row of rivets, as is also the case with the vertical seams of the sides, but all other longitudinal seams are single-riveted. The edges of the plates both in the bottom

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and in the sides are planed, and the work generally is equal to the best boiler work. All joints are made iron to iron, and caulked inside and out. Each tank is provided with a disk or false bottom, $\frac{3}{16}$ inch thick and 66 feet in diameter, which rests upon a bed of thin boards and sand, interposed between it and the foundation, in order that the tank may take an even bed (Fig. 14, Plate 7).

The smaller tanks, 47 feet in diameter, are made in the same manner, except that the thickness of the sides is slightly reduced. They were constructed under a guarantee for tightness, and after erection were tested by filling with water. Each is fitted with a 4-inch emptying and a 6-inch filling-pipe, with screw-valves, and furnished with a joint so that the orifice of each can be lifted up clear to the crown of the tanks by a hauling chain which passes over rollers at the top, and is brought down to the level of the ground outside, where it is worked by a small winding-gear. The orifices can thus be maintained at about the surface of the oil so as to avoid the possibility of drawing off any water that may have accidentally got into the tank, and which being heavier than oil would sink to the bottom, and also the vibration and ebullition which would occur in filling against a head of pressure. Each tank is provided with an external glass gauge from top to bottom, in lengths of about 4 feet, fitted with brass cocks, and each tube over-lapping the other so as to show the height of the oil in the tank. A light iron ladder on the outside gives access to the roof, and another is fixed from one of the man-holes to the bottom inside.

The contract was given to Messrs. Lysaght & Co. of Bristol, and the cost was about £4,000. The tanks are painted preferably white outside, and are provided with a ventilator at the top.

The operation of filling is as follows:—When a petroleum vessel arrives in port she is moored at the proper berth; her petroleum-pumps are then connected with the pipe on the quay, the valve of any particular tank required to be filled is opened, and the pumping commenced. As soon as the oil has been pumped out of the ship the valve at the stand-pipe is closed. At this stage of the proceedings the whole line of the feed-pipe from the quay to the storage tank will be full of oil. To facilitate the extraction of this the feed-pipe has a slight fall at each end to a point near the filling-house, where a small Worthington pump is attached, and the contents of the pipe are transferred into a small tank in the filling-house.

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Cooperage-Department.

This consists mainly, as shown on Figs. 11, 12 and 13, of a two-storied brick building about 100 feet by 38 feet, in which the work of cooperage generally is carried on. At one end is erected the boiler-house, in which is a Cornish boiler, 26 feet by 6 feet 6 inches diameter, with the usual tanks and donkey-pumps. Adjoining the end of the boiler-house is the steaming-house, where the barrels are first steamed and then dried. At the south end of the cooperage the empty barrels are stored in the yard, from which they are taken to be cleaned and repaired prior to being sent to the filling-house. The details of the plant are as follows :—

At the end of the boiler-house, Figs. 14 and 15, Plate 8, there is a large air-heating chamber filled with a coil of small pipes supplied with steam from the boiler. This chamber is connected with the blower by the pipe A A, which enters it at the bottom and passes out at the top and down to the ground by the pipes B B B, and is connected with the main air-pipe laid underground along the side of the steaming- and drying-house. Three branches are taken from this main air-pipe at C C C, leading into the three underground pipes D D D, from which are taken short branches E E E E of 1-inch pipe, about 2 feet apart, and spaced so as to exactly fit the bung-holes of the barrels, which are placed over them in three nests of eight barrels each. The main and branch air-pipes are fitted with valves at G G G, for the purpose of shutting off either the whole or any one of the nests. Similarly steam is taken from the boiler through the pipe H into the main steam-pipe O, from which it passes into the branches P P P, leading into the branches C C C of the air-pipes. A set of barrels is taken from the empty stock and rolled on to wooden carriages with the bung-holes over the branches E E E. The main steam-valve Q and the branch valves are opened, and the steam passes along C, D and E into all the barrels for ten to fifteen minutes. It is then shut off at Q, and the main hot-air valve F and its branch valves opened, the blower set to work, so as to drive hot air through the same branches C, D, E, until the barrels are perfectly dry, after which they are rolled into the cooperage for any necessary repairs. A large steam-jacketed glue-kettle is arranged as shown in Figs. 12 and 13, Plate 7. The repaired barrels receive a charge of hot glue, and are rolled along carriages over zinc-lined troughs, laid below the floor-level, and stored over them with the bung-hole down. The surplus glue is pumped

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back to the glue-kettle (Fig. 12). After this the barrels are lifted on to the floor above by the elevator D (Fig. 12), which is worked by a small separate engine; there they receive a coat of paint, and are then ready for sending down the run to the filling-house. The painting is done with large flat brushes, with such expedition that a skilled man is said to be able to paint fifteen hundred barrels per day.

The boiler and steaming and drying plant were supplied by the Uskside Engineering Company, Newport, Mon.

Filling- or Barreling-off Department.

This department is situated at a point near the jetty (see general plan, Fig. 1, Plate 7), and consists of a simple brick building about 46 feet by 32 feet (Figs. 16, 17, 18 and 19, Plate 8). The main floor, which is of wood, is about 6 feet above the ground, and has a 10-foot platform all round, communicating with a long platform at a lower level, about 150 feet by 30 feet. This long platform is at the level of the floor of the railway trucks, and is used for taking empties or loading up full barrels to be sent by rail. In the centre of the filling-house are two rectangular wrought-iron tanks about 12 feet by 4 feet by 4 feet, raised about 3 feet above the floor, and provided on each side with a number of 1-inch filling pipes, about 2 feet apart (Fig. 16). From the main storage-tanks to the filling-house tanks a 4-inch screw-jointed pipe is laid similar to the 6-inch main already described (Fig. 17). The arrangement of branches under the filling-house, from the 4-inch and 6-inch pipes, is as follows:—The 4-inch branch A leads from the main emptying-pipe into the two small tanks; the 4-inch branch B is carried round to the pump, and by C to pipe A; another branch D is carried from the 6-inch pipe into branch C; the main-pipe draining-branch E is carried from the point F to the pump. All these branches are fitted with screw-valves as shown at *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i* (Fig. 17).

Oil in the ordinary way flows by gravitation from one of the large storage-tanks by the 4-inch pipe, and along A into the two small barreling tanks, until they are filled, the valves *e*, *f*, *g*, *h* being closed and the rest worked as required.

When the oil in the large storing-tank has been lowered so that it ceases to flow by gravitation, it is raised by pumping, and passes along B to the pump, and thence through C and A, into the barreling tanks, the valves *a*, *b*, *f*, *h* being closed, and *c*, *d*, *e*, *g* opened. When the main filling-pipe is being emptied, as already

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described, the valves *h*, *e*, *c*, *d* are opened and *a*, *b*, *f*, *g* closed, and the remaining oil pumped along E C and A into the barreling tanks.

As it may sometimes be necessary for repairs to take the oil out of one storage tank and put it into another, a branch D is laid from the 6-inch filling pipe No. 1 to C, and the transfer of oil from one tank to another takes place by gravitation from the tank through the 4-inch emptying pipe No. 2, along B, to the pump, and thence along C and D into pipe No. 1 passing on to the other tank, as if it was being pumped from a vessel; in this case valves *g* and *f* are opened and valves *a*, *b*, *c*, *d*, *e*, *h* and *i* are closed. It will be seen that this arrangement of pipes gives the foreman at the filling-house complete control over the direction taken. A Worthington pump is used with a cylinder 8 inches in diameter and about 10 inches stroke.

A little above the floor-level, and running the entire length of the barreling tanks, two iron waste-troughs are fixed. The process of barreling is as follows:—Empties are rolled up off the long platform into the filling-house and put on these troughs close together, as shown in Figs. 16 and 18, with the nozzles from the tanks dipping into the bung holes. When filled they are rolled down the barrel-run to the jetty, or if required to go away by rail, to the siding. To prevent barrels from being overfilled, an American automatic filler, ingeniously arranged with a pneumatic sliding piston and spring shut-off, which can be so set as to regulate the speed of filling, is attached to the nozzles of the tank by a flexible tube. The pneumatic piston rises with the oil, and when the barrel is filled, the spring shut-off is released and the supply stopped.

The tank steamers for conveying petroleum to England range from 2,000 up to 4,000 tons carrying capacity. The engines and boilers are usually aft, the petroleum hold occupying almost the whole of the remaining portion of the ship. The hold is divided along the centre as well as across by several bulkheads (Figs. 20 and 21). By the kindness of the builders, Sir W. G. Armstrong, Mitchell and Co., the Author has been able to give a drawing of one of these ships, which was constructed according to the design of Mr. Swan. It will be seen on reference to the cross-section, Fig. 21, that the petroleum hold is made considerably narrower above the level of the water-line, the object of this arrangement being to ensure that the main part of the hold should be perfectly full, the narrow part at the top giving ample facilities for the expansion of the oil. If the petroleum were contained in one

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hold of the ordinary shape, not perfectly full, the stability of the vessel would be seriously affected. A pump is provided capable of discharging from 100 to 120 tons an hour, the suction-pipe of which has a branch fixed to each of the separate holds.

Cardiff Installation.

This installation has just been erected by the South Wales Public Wharf, Warehouse and Transit Company, Limited, Cardiff, and is situated on a stretch of land on the banks of the Ely, and about one mile from the Bute Docks, Cardiff (Fig. 22, Plate 8). The River Ely is a small tributary running into the Bristol Channel, and joins the mouth of the River Taff in what is known as the West Muds, opposite the Port of Cardiff. The Public Wharf Company have erected upon this tongue of land extensive wharves and warehouses, which are fitted in the most complete manner with hydraulic cranes, grain-warehouses, cellars, &c. The site possesses several hundred yards of deep-water frontage to the Ely, and good railway communication.

The petroleum installation is situated at the southern end of the site. It is enclosed by an embankment of earthwork similar to that at Avonmouth.

Storage Department.

From the wharf, at the point A on the plan (Fig. 22), a cast-iron 7-inch filling-pipe is laid to the storage department with branches to the five tanks, three of which hold nearly 1,300 tons each, and the two others about 1,000 tons each.

The branches from the main filling-pipe are of copper, and are bent up in a saddle-back form to allow for expansion. The tanks are in all respects similar to those at Avonmouth, and are fitted with gauge-glasses and jointed internal feed-pipes, &c. They stand upon a concrete foundation about 3 feet thick, resting on gravel. The surface of the foundations in their vicinity is finished with a cement-rendered floor, proper facilities being provided for collecting any leakage of oil. The emptying pipe is of cast-iron, 4 inches in diameter, and is laid from the bottom of the tanks to the filling-house (Fig. 22, Plate 8). An auxiliary feed-pipe is being laid with branches into the tanks, and a portable oil-pump made by the East Ferry Engineering Company, capable of delivering 120 tons per hour, will be connected with it so as to supplement the ship's pumps and discharge the vessel in half the time. After

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discharging, the ships receive their coal-supply without changing their berths. A new wharf is being constructed in a more convenient position.

Cooperage-Department.

The general arrangement of this department is shown in Fig. 22, Plate 8. It consists of a shed of corrugated iron, at the end of which is placed the boiler-house, and is fitted with a steaming and drying apparatus at C, glue-kettle and troughs at D, and a painting and branding house at E.

The empty barrels are stored in the yard at F, whence they are taken to the steaming and drying department, repaired, glued, and sent forward to the painting department. Barrel-runs are freely used, and are for the most part of a portable description.

Barreling-off Department.

This is situated at the end of the long painting floor, which is elevated to about the level of the bottom of the railway trucks, and is arranged similarly to the one already described at Avonmouth. Two men can fill and bung 1,200 barrels per day.

Under the present system of distribution by barrels great loss is incurred, not only in filling and in carriage, but also from the large waste of space between the barrels when loaded, the expense on the returned empties, and the necessary repairs and cooperage. To avoid this loss this company have adopted the use of 10-ton tanks, mounted on railway trucks, which are filled and consigned direct to the dealers, carriage being paid only on the net weight of the oil. The dealer can either retain the tank in his siding until emptied, or he can have his own small storage tank into which the oil is discharged, the portable tank being consigned back to the depot. It is probable that this system of distribution will shortly become general.

The Author expresses his thanks to Mr. Robert Johnston for supplying him with information concerning the Cardiff installation.

The Paper is accompanied by six tracings, from which Plates 7 and 8 have been prepared.

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(*Paper No. 2506.*)

"A Method of Calculating the Area of a very Irregular Cross-Section of a Railway Cutting without the necessity of Plotting."

By F. H. BREAKELL.

THE operation of levelling is performed in the ordinary way by booking the "sights" at every important change in the inclination of the natural surface, commencing at a peg well beyond the edge of the proposed excavation, and proceeding across to a corresponding one on the other side. These "reference pegs," as they may, for convenience sake, be called, serve as permanent marks by means of which the exact centre of the work may be ascertained at any stage of its progress. After the cutting has been taken out, the levels are read over the excavated surface from "edge to edge of cutting," but in an opposite direction to the natural surface levels, the reading at the terminal or "foresight" reference peg being entered as a "backsight," because it is necessary that the sights should appear consecutively round the figure showing the limits of the cross-section. The reason for this will appear more clearly further on.

The zero of the distances (which are distinguished by opposite signs, according as they are right or left) must be on the same vertical line or "meridian" for both sides of the cutting, whether in natural surface or excavation levels, and this vertical line may be supposed to pass through the centre, or indeed any other point; but for the sake of convenience it should intersect the base of the cutting in preference to either of the slopes.

After the levels have been entered as stated it will be found that there are more natural-surface levels than are required—for instance, the reading at the reference pegs, and possibly others. These will be easily found by inspection, as those natural-surface levels which have a greater distance reading than that of the "edge of cutting" in the excavation levels are, of course, unnecessary, and must be struck out before commencing the calculations. In the specimen page of a Level-Book which accompanies this Paper (page 261) —such cases are indicated by the figures being printed in italics—

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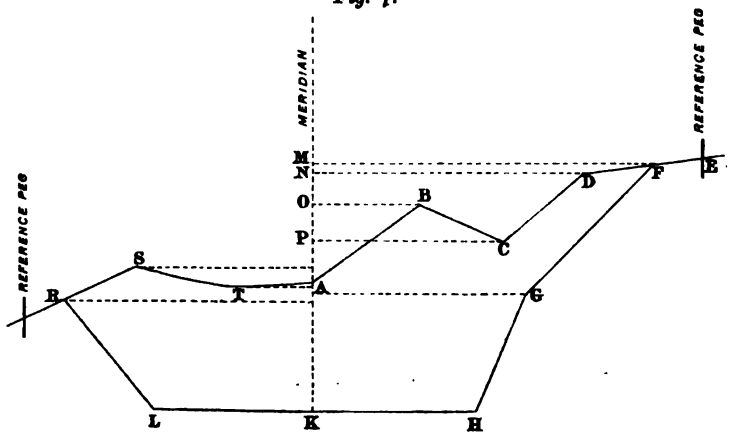
thus it will be seen that the edge of cutting F on the right side is at 34·80 feet from the centre or meridian, whilst the sight immediately above it—that of the reference peg E—is at 40 feet, and must be crossed through. The sight at D is evidently inside the cutting, its distance being less than that of the "edge," and it must therefore be left intact; but the difference of level (rise 1–10) between D and F must be obtained from the reduced levels and noted accordingly. The superfluous levels on the left side are eliminated in the same manner. It is well before going any further to total up the rises and falls, and if the results are equal the alterations have been correctly performed.

The levels and distances having been recorded as directed in columns Nos. 1 to 7 inclusive (which are the same as in the ordi-

Fig. 1.



nary Level-Book), the "double longitudes" are next calculated by adding each distance to the one immediately preceding, the results being placed in column 8. In commencing, the first sight inside the cutting (S), has to be added to that of the "edge" (R), which is entered in its proper place at the end of the excavation levels.

The following explanation may not be considered out of place, as the "double longitude" method is rarely dealt with in works on engineering. Assuming the vertical line before mentioned to be a "meridian," the distances O B, P C, N D, see *Fig.*, &c., are the "longitudes" of the points B C D, &c., with respect to it, and the sum of the "longitudes" of any two consecutive points is equal to double that of the centre of the line of which these two points are the extremities; hence the term "double longitude."

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SPECIMEN PAGE OF LEVEL-BOOK.

1 B.S.	2 Int.	3 F.S.	4 Rise.	5 Fall.	6 Red. level.	7 Distance.	8 Double Longitude.	9 Multipliers.	10 + Products.	11 − Products.	Remarks.
18·80	..	..	..	..	15·80	− 30·00	..	..	..	..	Left Nat. Sur. Ref. peg.
..	13·10	..	3·55	..	21·50	− 19·00	− 44·8	+ 3·5	..	− 157·2	„ „ (S)
..	14·90	..	..	1·80	19·70	− 9·30	− 28·3	− 1·8	+ 50·9	..	„ „ (T)
..	14·60	..	0·30	..	20·00	+ 0·00	− 9·3	+ 0·3	..	− 2·8	Centre „ (A)
..	6·80	..	7·80	..	27·80	+ 10·70	+ 10·7	+ 7·8	+ 83·5	..	Right „ (B)
..	10·30	..	..	3·50	24·30	+ 19·50	+ 30·2	− 3·5	..	− 105·7	„ „ (C)
..	3·60	..	6·70	..	31·00	+ 28·00	+ 47·5	+ 6·7	+318·3	..	„ „ (D)
4·80	..	1·60	*2·00*	..	*33·00*	+ *40·00*	..	..	..	..	„ „ Ref.peg.(E)
1·20	..	5·70	1·10	*0·90*	32·10	+ 34·80	+ 62·8	+ 1·10	+ 69 1	..	„ Excav. Edge (F) of cutting.
2·20	..	14·60	..	13·40	18·70	+ 21·80	+ 56·6	− 13·4	..	− 758·2	„ „ (G)
..	14·30	..	..	12·10	6·60	+ 16·70	+ 38·5	− 12·1	..	− 465·9	„ „ (H)
..	14·30	..	..	0·00	6·60	+ 0·00	+ 16·7	..	..	..	Centre „ (K)
..	14·30	..	..	0·00	6·60	− 16·70	− 16·7	..	..	..	Left „ (L)
..	..	2·95	11·35	..	17·95	− 25·80	− 42·5	+ 11·4	..	− 484·5	„ „ Edge(R) of cutting.
..	..	..	30·80	30·80	..	202·30	404·6	..	+521·8	−1974·3	
..	..	..	..	..	..	..	..	..	..	+ 521·8	
										2 −1452·5	
										− 726·2 = Area of cross-section.	

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The correctness of the "double longitudes" is proved by adding up the figures in the columns 7 and 8, not noticing the signs, and if the total of the "double longitude" column (8) is double the total of the distance column (7), the results are correct. In column 9 are placed the plus and minus multipliers, which are simply the rises and falls. In column 10 are placed the plus, and in column 11 the minus products which are obtained by multiplying the "double longitudes" by the rises and falls or plus and minus multipliers.

PART OF CROSS-SECTION TO RIGHT OF "MERIDIAN."

Sums of pairs of distances.	× Falls.	= Areas.		
(MF + AG)	× MA	= Twice the area of figures	MFGA	= 2 (MFGHK + OBCP).
(AG + KH)	× AK	= „ „ „	AGKH	
(OB + PC)	× OP	= „ „ „	OBCP	

	Rises.			
(OB)	× AO	= Twice the area of figures	ABO	= 2 (ABCDFM + OBCP).
(PC + ND)	× PN	= „ „	(OBCDN + OBPC)	
(ND + MF)	× NM	= „ „ „	NDFM	

Subtracting the less from the greater the result is 2 (ABCDFGHK) = twice the area of the cross-sections.

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(Paper No. 2528.)

"Oil-Gas Tire-Setting Apparatus in the Grand Trunk Railway Company's Works at Montreal."

By FREDERIC LUMB WANKLYN, Assoc. M. Inst. C.E.

(Abstract.)

THE object of this Paper is to describe an apparatus for producing oil-gas from refined petroleum having a flashing-point of 95° Fahrenheit; and for burning this gas with heated compressed air for the purpose of expanding railway tires before placing them upon, or removing them from, locomotive or wagon wheels.

The apparatus is the invention of Mr. T. W. Gentry, and has been erected under the supervision of the Author, at the workshops of the Grand Trunk Railway, in Montreal. It consists essentially of four cast-iron cylindrical vessels, 11¾ inches diameter, 8 feet long, and 1½ inch thick, built into an ordinary coke- or coal-heated furnace. Three of these vessels, having been brought to a red-heat, are used for vaporizing the oil, and the fourth for heating the air, which is supplied at a pressure of 30 to 40 lbs. per square inch from a reservoir, fed by a standard 8-inch Westinghouse air-pump.

The oil is stored underground, outside the building, and is lifted by means of a 2½-inch hand-pump into a small tank in communication with the compressed air, by which it is forced through a pipe ⅜ inch in diameter, to an injector or regulator. Here it is blown into fine spray by means of a jet of cold air, and is carried forward in a pipe of the same diameter into the three hot vessels or retorts in succession. It is then conducted in the form of a rich smoky gas through about 25 feet of 1¼-inch wrought-iron pipe to the setting-house, where it joins the heated air, with which it passes through a short pipe to the perforated hoop-shaped tubes encircling the tires, and is there ignited.

A complete set of regulating valves controls the admission of oil and air to the retorts, beyond which point no obstruction should be placed, so that all possibility of accumulated pressure may be avoided.

The tire-setting shop is separated from the fire-proof building

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in which the oil-gas is produced. It is polygonal in plan, and the entire floor is covered by a 5-ton rotary bridge-crane, having a span of 22 feet, and a lift of 14 feet. The wheels and tires are placed in position by this crane, the oil-gas and air mixture being brought through flexible pipes to the ring-burners.

At a trial of the complete apparatus in December 1890, two and a half hours were occupied in heating and setting three pairs of tires, 6 feet $1\frac{5}{8}$ inch, 3 feet 7 inches, and 3 feet 1 inch diameter respectively, and from $3\frac{1}{8}$ inches to $2\frac{9}{16}$ inches thick, including one hour taken to heat the retorts. In this operation 5·78 gallons of oil, worth in Canada 6*d.* per gallon, were vaporized. The work was accomplished by three men, whose wages amounted to 3*s.* $7\frac{1}{2}$*d.*, bringing up the total cost of fuel and labour to 8*s.*

Two sets of apparatus have been successfully worked at Montreal for twelve months, the cost of maintenance being nil.

The advantages claimed for this method of tire-setting are, cleanliness, economy, and absence from risk of fires. The chances of failure or accident are not greater than when ordinary illuminating or coal-gas is used. The apparatus is easily controlled, and the generation of gas started or stopped by opening or closing the oil-valve placed between the small oil-tank and the injector.

The original was accompanied by three blue prints.

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(Students' Paper No. 276.)

"The Counter-balancing of Locomotive Engines."[1]

By EDMUND LEWIN HILL, Stud. Inst. C.E.

HISTORY OF BALANCING.

THE discovery that for a wheel to run smoothly it must be balanced, or, in other words, must have its centre of gravity coincide with its centre of motion, is without doubt of prehistoric date, though the reasons for this necessity and the rules which arise from them have only been properly understood and acted upon for a comparatively short time. One of the earliest instances of balancing was the method formerly adopted with respect to water-wheels. These used to be made of wood, and if they were allowed to stop for any length of time, the part above water would dry while that below would remain wet, so that the wheel on starting again would run in a succession of jerks, being heavier on one side than on the other. To obviate this it was usual to keep the wheel moving very slowly instead of stopping it altogether.

Mr. Heaton[2] was probably the first to counterbalance the disturbing force on a locomotive engine by a weight in the wheel. In 1831 he and his brothers made a common road steam-carriage, and found that at a speed of 160 revolutions a minute the shaking was so violent that they could not keep their seats. Mr. Heaton described his plan in a letter to the "Mechanics' Magazine," April 8th, 1842,[3] as follows:—"Being aware that this motion could only be produced by some portions of our machinery being out of balance, we placed a compensating weight opposite each crank, and . . . . . found we attained greater speed with no greater consumption of fuel, and the machine travelled perfectly steadily at any speed and free from any symptoms of rocking or shaking." This was only taking into consideration the revolving weights. It was a long while before a practical method of balancing the reciprocating weights of locomotives was pro-

[1] This communication was read and discussed at a meeting of the Students on the 30th of January, 1891.

[2] *Engineer*, 30 January, 1880, p. 77.

[3] *Mechanics' Magazine*, 8 April, 1842, p. 279.

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posed, though the necessity of doing so was seen by many engineers. At an early date the Stephensons had tried on the Liverpool and Manchester Railway to minimize the action of the reciprocating parts by diminishing the length of stroke and increasing the diameter of the cylinder, but this method was given up because the engine used too much steam.[1]

Mr. Bodmer[2] in 1834 proposed to entirely destroy the action of the reciprocating parts by having two pistons working in one cylinder with the piston-rods issuing at opposite ends and connected to a double crank, and in 1841 he modified this plan by making the two piston-rods work one inside the other from the same end of the cylinder.[3] He built some of these engines for the South Eastern Railway, and one was stationed at New Cross in 1845.[4] Mr. Weallens in 1836 brought out a four-cylinder engine with the same object.[5]

In 1837 Mr. Braithwaite, of the Eastern Counties Railway, Mr. Richard Roberts, of Sharp, Roberts and Co., and Mr. Rogers and Mr. Griggs in America, began to balance the revolving parts of locomotives by a weight in the wheel.[6]

Mr. Heaton, who had been experimenting on the subject, made in 1838 a model of the wheels and crank-shaft of a locomotive to show the effects of unbalanced moving-parts, and submitted it to the Resident Engineer at Birmingham of the London and Birmingham Railway. The Company's engine "Brockhall," which was being repaired at the time, was ordered to have balance-weights applied to it under Mr. Heaton's supervision, and the result being satisfactory, all the company's engines were balanced in the same way.[7] In 1842 Mr. M'Connell began to use Mr. Heaton's plan on the Birmingham and Gloucester Railway,[8] and in the same year Dr. Melson read a Paper on balancing, probably the first written on the subject, before the Birmingham Philosophical Institute.[9]

In February 1843 Mr. Crampton, in a letter to the *Railway Times*, pointed out that one of the causes of unsteadiness in

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[1] Minutes of Proceedings Inst. C.E., vol. viii. p. 260.
[2] *Ibid.*, vol. xxii. p. 92.
[3] *Ibid.*
[4] Report of the Gauge Commissioners—Carriages, Question 4,293.
[5] Minutes of Proceedings Inst. C.E., vol. xxii. p. 102.
[6] "Locomotive Engineering." By Colburn, p. 51.
[7] *Engineer*, 30 January, 1880, p. 77.
[8] "Railway Machinery." By D. K. Clark, p. 165.
[9] *Mechanics' Magazine*, 9 April, 1842, p. 276.

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engines was that the reciprocating parts were unbalanced, but he did not suggest any method by which this could be remedied. Mr. Fernihough was the first to propose and carry out the balancing of the reciprocating parts by a weight in the wheel. This he did in his engines on the Eastern Counties Railway in 1845, and he described his plan before the Gauge Commissioners in that year.[1] In 1847 Mr. Heaton brought forward a device for effecting the same purpose, which consisted of a double crank with one connecting-rod attached to the piston-rod and another to a dummy weight working in slides under the foot-plate by the side of the fire-box. This plan was used for some years on the London and Birmingham Railway.[2] In 1838 Mr. E. A. Cowper had proposed to balance a quick-working rubber-cutter in exactly the same way by a dummy weight. This, however, was never carried out, because of the expense.[3]

In 1847 Mr. Haswell, Locomotive Superintendent of the Austrian State Railways, also brought out an engine similar in idea to Bodmer's, but with two cylinders on each side, one on the top of the other, working on to double cranks.[4] This engine, which was named "Duplex," was still in use in 1873.

Mr. Nollau, Locomotive Superintendent of the Holstein Railway, was the first to go thoroughly into the theory of balancing. In 1847 he conducted elaborate experiments on the subject, the results of which are embodied in an article by him in Mr. Couche's work on "Permanent Way Rolling Stock."[5]

Nollau was followed in 1848 by Le Chatelier, who wrote a treatise on the question,[6] and Mr. D. K. Clark in 1852 published an account of his investigations, together with the rules deduced from their results, which have since been almost universally employed.[7]

Since then the disturbing forces of locomotives have always been balanced in the wheels, and though many other methods of balancing have been invented they have never been adopted in practice. Among them may be mentioned Mr. Resal's plan in 1853 of applying a dummy weight on the prolongation of the connecting-

[1] Report of the Gauge Commissioners. Question 4,294.
[2] *Engineer*, 30 January, 1880, p. 77.
[3] Minutes of Proceedings Inst. C.E., vol. xxii. p. 95.
[4] "Modern Mechanical Engineering." By R. Scott Burn. p. 191.
[5] "Permanent Way Rolling Stock." By C. Couche. Vol. ii. notes p. 783.
[6] "Railway Machinery." By D. K. Clark, p. 177.
[7] "Recent Practice in the Locomotive Engine." By Clark and Colburn, p. 45*.

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rod;[1] Mr. Makinson's single-cylinder engine in 1862;[2] a four-cylinder double-crank engine, built about 1880 by Mr. Shaw, an American engineer;[3] and another by the same maker in 1882 with oscillating cylinders placed between the driving-wheels with two pistons in each cylinder connected direct to the crank-pins;[4] and, lastly, Mr. Crampton's four-cylinder tank-engine with two pairs of single driving-wheels, the front pair of which are actuated by the two right-hand cylinders and the back pair by those at the left side, each set of cylinders working on to a double crank.[5]

Theory.

The moving parts of a locomotive which cause disturbance may be divided into two classes, revolving and reciprocating, the former comprising the cranks and side-rods, and the latter consisting of the piston, piston-rod, and cross-head. The connecting-rod cannot properly be classed under either of these heads, since the small end, which moves in a straight line, is reciprocating; the big end, which describes a circle, is revolving, while all the intermediate points describe ovals of various magnitudes. It is usual to consider part of the rod as reciprocating and part as revolving, and in the relative proportions taken there is a wide difference in practice.

The revolving parts as they move round develop centrifugal force, the horizontal component of which throws a stress on the engine longitudinally, and causes recoil backwards and forwards.

At the same time the vertical component tends to reduce the adhesion between the wheels and rails, and to cause slip on the top half-stroke, and pounds the wheels against the rails on the bottom half-stroke. This vertical force, by acting first on one side of the engine and then on the other, produces also a rolling movement from side to side.

To the fore-and-aft motion, caused by the horizontal component of the centrifugal force of the revolving parts, must be added that due to the momentum of the reciprocating parts. These have to be brought to rest at the end of each stroke, and the steam-pressure required for starting them again acts with equal and opposite effect on the cylinder-head, imparting, when at the front

[1] "Permanent Way Rolling Stock." By C. Couche. Vol. ii. p. 349.
[2] Minutes of Proceedings Inst. C.E., vol. xxii. p. 75.
[3] Transactions of the American Society of Mechanical Engineers, vol. ii. p. 277.
[4] *Railroad Gazette*, 17 February, 1882, p. 99.
[5] Société des Ingénieurs Civils, Paris, 5 March, 1886.

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dead centre, a forward movement to the engine.[1] This force decreases until the piston reaches its position of maximum velocity, when acceleration ends and retardation begins, and continues to increase until the piston arrives at the end of the stroke. During this retardation the pressure which was absorbed in producing the acceleration is given out again, and imparts a backward movement to the engine. Thus the horizontal component of the centrifugal force of the revolving parts, together with the varying pressure caused by the acceleration and retardation of the reciprocating parts, causes a movement of the engine alternately backwards and forwards.

These two forces do not always act together. Owing to the obliquity of the connecting-rod the reciprocating parts arrive at their position of greatest velocity before half-stroke, at which point the disturbance caused by them changes in direction—on the bottom part of the stroke from forwards to backwards, while that of the revolving parts is still acting forwards. On the top half-stroke the contrary effect occurs, the momentum of the revolving parts beginning to act forwards, while that of the reciprocating parts is still directed backwards. This force, which alternately gives the engine a forward and a backward movement, causes also a sinuous movement by acting first on one side and then on the other.

The obliquity of the connecting-rod produces also pressure on the slide-bars, varying from nothing at the dead-centres to a maximum at half-stroke. This pressure under ordinary conditions acts upwards during forward running, and inasmuch as one piston is at half-stroke when the other is near the dead-centre, it produces a rolling motion from side to side round a longitudinal axis. At the same time it also causes an up-and-down movement of the whole engine round the driving-axle—"galloping"—and the galloping and rolling together produce an "elbowing" motion.

Since the only practical way of balancing an engine is by a weight in the wheel, it remains to be determined how nearly perfect equilibrium can be attained by this method. If the connecting-rod were of infinite length the disturbing force would increase or decrease with the cosine of the crank-angle, and its equation would be

$$\text{Disturbing force} = m\, r\, \omega^2 \cos\theta$$

(m being the mass of the moving parts, r the radius, and ω the angular velocity of the crank). At the dead-centre, $\cos\theta = 1$,

[1] See Appendix IV.

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and the disturbing force is then $= mr\omega^2$, that is to say, the centrifugal force. If then a mass whose centrifugal force equalled $mr\omega^2$ were placed opposite the crank the engine would be perfectly balanced as to its fore-and-aft motion. But the effect of the finite length of the connecting-rod is that the disturbing force varies with the expression

$$\cos\theta + \frac{n^2(\cos^2\theta - \sin^2\theta) + \sin^4\theta}{(n^2 - \sin^2\theta)^{\frac{3}{2}}},$$

where n is the ratio of the length of the connecting-rod to that of the crank. This formula is given by Mr. Imray in his Paper on "High-Speed Motors."[1] Now, since the horizontal component of the centrifugal force of the balance-weight varies with $\cos\theta$, there is a continual discrepancy between it and the disturbing force. The horizontal disturbances being far more injurious to the stability of the engine than those in a vertical direction, the Author proposes to determine how nearly it is possible to eliminate them.

The problem has been worked out for a 7-foot single-wheel express engine, the particulars of which are:—

Radius of crank	12 inches
Centres of cylinders	24 „
„ wheels	60 „
Radius of balance-weight	33 „
Weight of piston and appendages	350 lbs.
„ crank-blades and pin	430 „

The weight of the connecting-rod is 400 lbs., and it is assumed that the big end and half the length of the rod, which together weigh 250 lbs., are revolving with the crank, and that the small end and half the length of the rod, which together weigh 150 lbs., are reciprocating with the piston. This gives a total reciprocating weight of 500 lbs., and a total revolving weight of 680 lbs. The connecting-rod is 6 feet 6 inches long, and the crank being 12 inches the ratio of the two is as 6·5 to 1. The engine is in all cases assumed to be travelling at 60 miles per hour, at which speed a 7-foot wheel makes 240 revolutions a minute.

The disturbing influence of the reciprocating parts will be first considered. These weigh 500 lbs. At the dead-centre the crank, connecting-rod, and piston-rod, are all in one straight line, and this weight of 500 lbs. may be assumed to be acting as if fixed to

[1] Minutes of Proceedings Inst. C.E., vol. lxxxiii. p. 121.

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the crank-pin. The centrifugal force of it at the given speed is found to be 9,807 lbs., and the curves in *Figs. 1–6* represent the disturbing forces during 1 revolution.

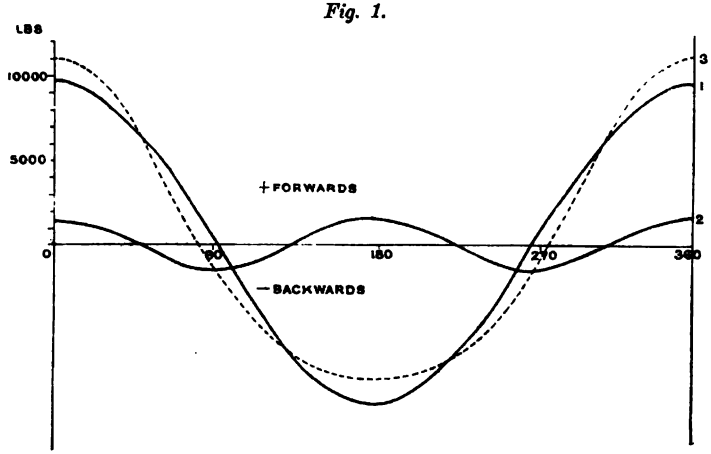
In order to show the effect produced by the obliquity of the connecting-rod, it has been assumed in the first place to be of infinite length, and the corresponding result is given in *Fig. 1*, curve No. 1.

Curve No. 2 represents the expression

$$\frac{n^2(\cos^2\theta - \sin^2\theta) + \sin^4\theta}{(n^2 - \sin^2\theta)^{\frac{3}{2}}},$$

which is the second term in Mr. Imray's formula for a connecting-rod of finite length, and shows how the disturbing force is

Fig. 1.



modified by the obliquity of the connecting-rod. Curve 3 is the sum of these two, that is to say, the graphic representation of the complete formula. It will be seen that the extra disturbance, caused by the finite length of the connecting-rod, is too great to be neglected.

It has been already stated that in the example selected, the centrifugal force of the reciprocating parts, assumed to be concentrated at the crank-pin, is 9,807 lbs. Now, the disturbing influence of the reciprocating parts, for successive crank-angles, is equal to this centrifugal force multiplied by the corresponding values of the expression

$$\cos\theta + \frac{n^2(\cos^2\theta - \sin^2\theta) + \sin^4\theta}{(n^2 - \sin^2\theta)^{\frac{3}{2}}}.$$

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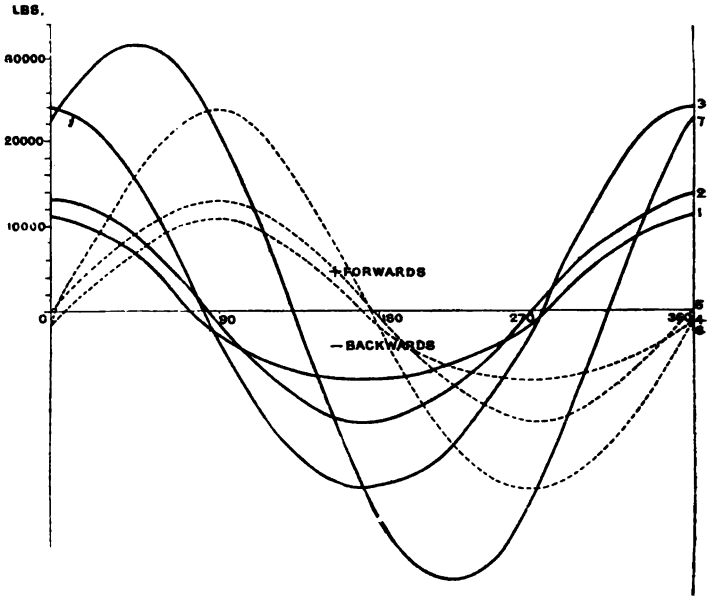
For instance, the disturbing force at the front dead-centre is 9,807 lbs. × 1·1538 = 11,315 lbs. Working out in a similar way the values for the other crank-angles, the data were obtained, from which curve 1, *Fig. 2*, representing the disturbing influence of the reciprocating parts for one revolution, was prepared.

To this has to be added the disturbing force caused by the revolving parts. These weigh 680 lbs., and their centrifugal force is 13,357 lbs. The horizontal component of this force produces a longitudinal disturbance, which varies with cos θ,

Fig. 2.



and is represented by curve 2, *Fig. 2*. Curve 3 shows the total disturbing force of the revolving and reciprocating parts combined.

Hitherto only one crank has been dealt with. To get the total disturbing force on the engine it is necessary to combine the effects of the moving parts on both sides. In *Fig. 2* the dotted line, curve 4, is that of the disturbing force of the reciprocating, and curve 5 that of the revolving parts of the other crank, 90° behind. Curve 6, *Fig. 2*, is the resultant of these two, and finally the thicker black curve, No. 7, obtained by combining

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curves Nos. 3 and 6, is that of the total longitudinal disturbing force due to both sides of the engine.

Sinuous Force.

So far only those forces have been considered which act backwards and forwards, and it is necessary now to examine the equally destructive disturbances which are directed sideways and give the engine a sinuous motion. Le Chatelier first pointed out that the force on each crank is not confined to its own wheel, but is exerted on both according to their respective distances from its line of action. The disturbing force of the revolving and reciprocating parts acting at one crank tends to turn the axle about its centre of gravity, and that at the other crank produces a similar effect on the opposite side of it. When the right-hand crank is on its front dead-centre there is a force of 24,672 lbs. on it directed forwards, and pushing the head of the engine to the left, and a force of 1,601 lbs. on the left-hand crank, acting backwards, and pulling the locomotive round in the same direction. Taking moments round the centre of the axle, the leverage being in each case 1 foot, there is found to be a total force of 26,273 lbs., turning the head of the engine to the left.

The algebraic sum of the turning forces of the two cranks during 1 revolution of the axle is given graphically in curve 1, *Fig. 3*, which represents the resultant sinuous force on the engine, and shows the necessity of so arranging the balance, if possible, that it shall counteract this turning force as well as the fore-and-aft disturbance.

It will be seen at once that an engine cannot be balanced, both as to its horizontal and vertical disturbances. If horizontal equilibrium is aimed at it must be got by a balance-weight, which, while counteracting the disturbance of the reciprocating parts by its horizontal action, will develop also a superfluous vertical force, thus causing a new disturbance. If, on the other hand, vertical equilibrium is required, the reciprocating parts must remain unbalanced.

As in the Author's opinion the horizontal disturbances are far more harmful than the vertical, the latter, which cause pounding, rolling, and galloping, will be omitted for the present until the method of counteracting the former has been dealt with.

Mr. D. K. Clark has fully explained this in his work on "Railway Machinery," and the rules which he there gives have been almost universally adopted.

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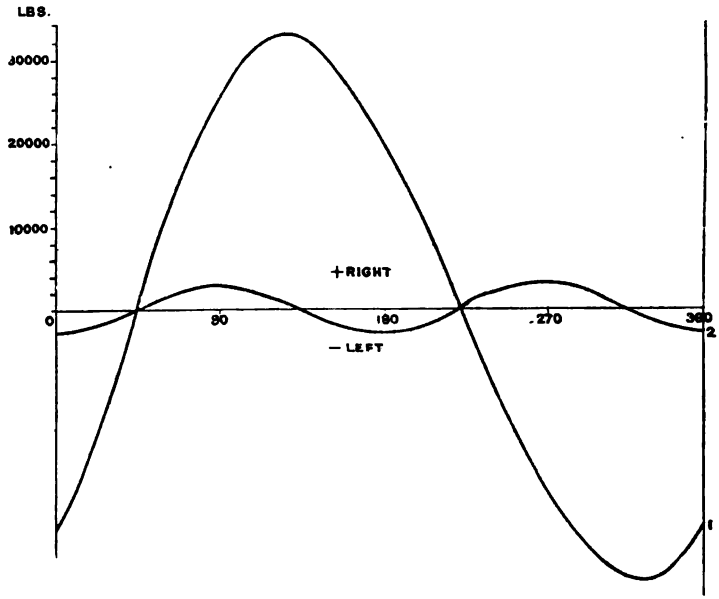
Since the weight of the moving parts, which has been assumed to be concentrated at the crank-pin, is not in the plane of revolution of the balance-weight, a couple will be left at each crank after its balance has been adjusted. The effect of these two couples will be to cause a sinuous motion of the engine about the centre of the crank axle, which must be got rid of by making the sum of the moments about the centre of the axle

Fig. 3.



of the two balance-weights and of the two cranks equal to zero.

This can be done by dividing each balance-weight into two parts and putting one in each wheel, so that, for example, the balance-weight of the left-hand crank is placed part upon the left-hand wheel and part upon the right-hand wheel.

It will be seen that, when the other side has been treated in a similar way, there will be two weights, a large one and a small one, in each wheel. By supposing these to move towards each other through a space inversely proportional to their masses, a position may obviously be found at which a single balance-weight may be placed so as to have the same effect as the pair. The

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weight of this is found by extracting the square root of the sum of the squares of the two weights. The formulas are

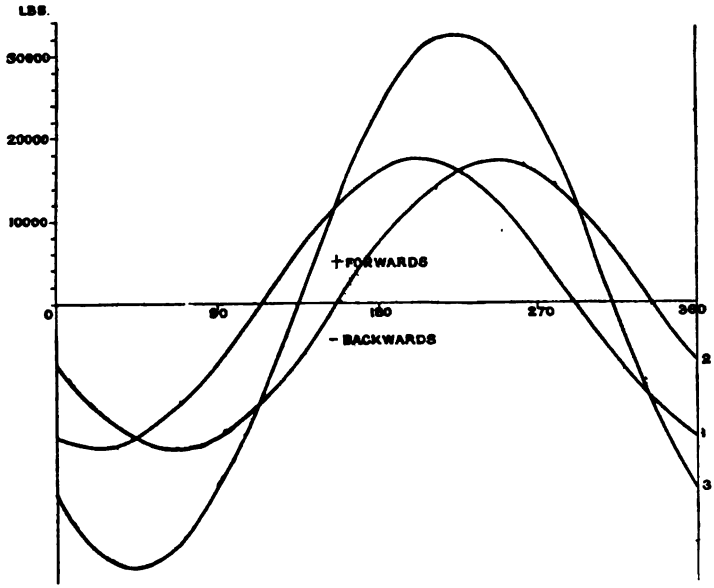
$$\mu, \text{ the large weight} = \frac{p}{2r} \cdot \frac{a+b}{a} \cdot \mathrm{M} \qquad (1)$$

$$\mu', \text{ the small weight} = \frac{p}{2r} \cdot \frac{a-b}{a} \cdot \mathrm{M} \qquad (2)$$

$$m, \text{ the resultant weight} = \sqrt[2]{\mu^2 + \mu'^2} \cdot \qquad (3)^1$$

To find the inclination of the balance-weights the smaller must

Fig. 4.



be divided by the larger; the result will be the tangent of the angle, which each balance makes with its own crank, diverging from it towards the other crank. As horizontal equilibrium is aimed at, the whole of the parts which cause disturbance must be balanced.

The application of these formulas to the engine under consideration, the disturbing parts of which weigh 1,180 lbs., gives 300 lbs. for the large weight, 128 lbs. for the small weight, and 326 lbs.

[1] See Appendix, p. 282.

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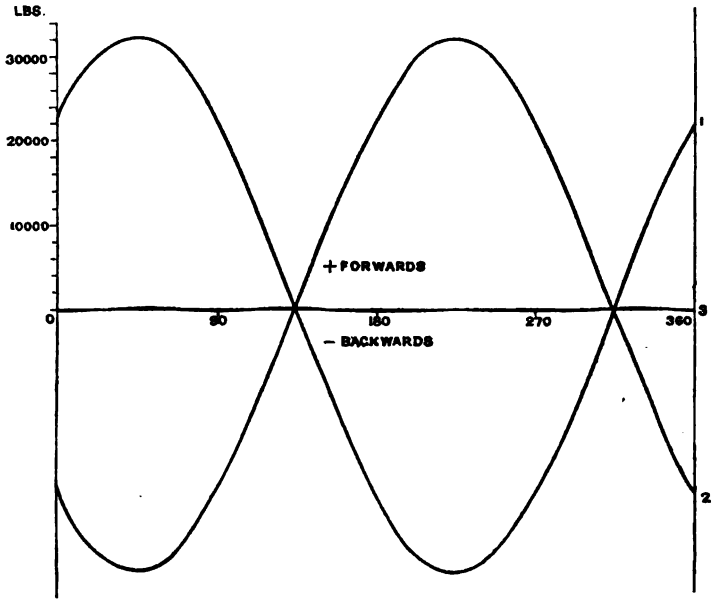
for the resultant weight, the centre of gravity of which is 33 inches from the centre of the wheel.

The angle, which each balance makes with its own crank, is found to be 23° (see *Fig. 9*, Appendix). The weight of the balance being 326 lbs., its centrifugal force equals 17,647 lbs. Now, the horizontal component of this force is the part which balances the fore-and-aft motion, and is equal to the centrifugal force multiplied by the cosine of the angle, which the balance-weight makes with the centre line of the engine.

Working this out for successive crank-angles, the Author

Fig. 5.



obtained curve 1, *Fig. 4*, as the expression of the horizontal component of the centrifugal force of the right-hand, and curve 2 as that of the left-hand balance-weight. Curve 3 shows the total horizontal force of the two balance-weights combined.

The result of the investigation is given in *Fig. 5*, in which curve No. 1 is identical with curve No. 7, *Fig. 2*, and represents the total longitudinal disturbing force, and curve No. 2 is the same as curve No. 3 of *Fig. 4*. It will be seen that the resultant, curve No. 3, *Fig. 5*, is so nearly a straight line that it can only be indicated by a slight thickening of the zero line, and the following

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Table is therefore given to show that the engine is almost perfectly balanced as regards its longitudinal movements. Decimal places have been neglected in the working.

+ *Forwards.* − *Backwards.*

Right Hand Crank.	Total Disturbing Force.	Total Balancing Force.	Resultant Disturbing Force.
°	Lbs.	Lbs.	Lbs.
0	+ 23,071	− 23,117	− 46
18	+ 29,146	− 29,152	− 6
36	+ 32,398	− 32,311	+ 87
54	+ 32,398	− 32,311	+ 87
72	+ 29,146	− 29,152	− 6
90	+ 23,071	− 23,117	− 46
108	+ 14,832	− 14,858	− 26
126	+ 5,161	− 5,117	+ 44
144	− 5,077	+ 5,117	+ 40
162	− 14,907	+ 14,858	− 49
180	− 23,257	+ 23,117	− 140
198	− 29,221	+ 29,152	− 69
216	− 32,314	+ 32,311	− 3
234	− 32,314	+ 32,311	− 3
252	− 29,221	+ 29,152	− 69
270	− 23,257	+ 23,117	− 140
288	− 14,907	+ 14,858	− 49
306	− 5,077	+ 5,117	+ 40
324	+ 5,161	− 5,117	+ 44
342	+ 14,832	− 14,858	− 26
360	+ 23,071	− 23,117	− 46

Sinuous Motion.

It remains to be seen whether the engine is also balanced as to sinuous motion. When the right-hand crank is on its front dead-centre, the force of the corresponding balance-weight is pulling the head of the engine to the right; those of the left-hand crank and left-hand balance-weight are pulling it to the left, and the force of the right-hand crank is pushing it to the left. For lateral equilibrium, the sum of the moments of all these forces round the centre of the axle should vanish. Working this out for successive crank-angles, curve 2, *Fig. 3*, is found to represent the resultant sinuous force on the engine, and shows that while the longitudinal disturbing force is practically destroyed, the sinuous disturbing force is very much reduced.[1]

[1] See Appendix, p. 285.

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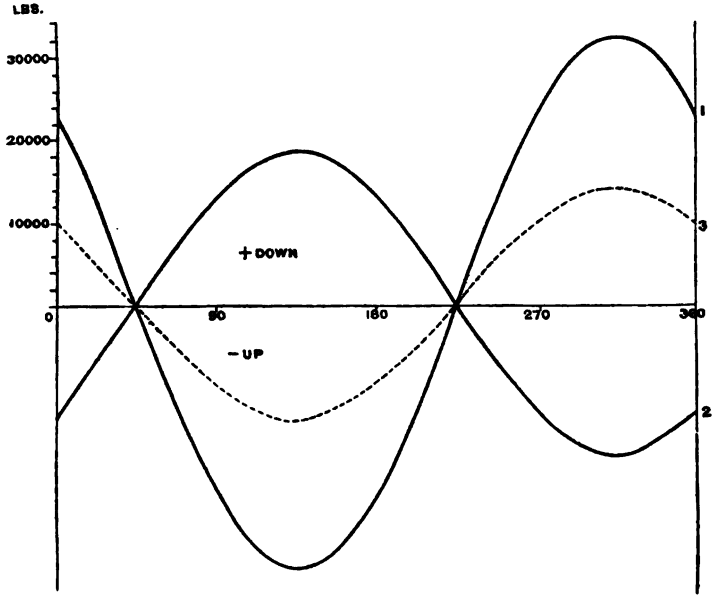
Vertical Forces.

In order to balance the reciprocating parts, which produce only horizontal disturbances, a weight has been added, which has both horizontal and vertical action. There results from this a superfluous vertical action. Taking the total vertical force of each balance-weight, which is equal to its centrifugal force multiplied by the sine of the angle which the crank makes at any moment with the centre line of the engine, and combining the action of the two, a curve is obtained which is represented by curve No. 1, *Fig. 6.*

Fig. 6.



But part of this vertical action is neutralized by that of the revolving parts, which equals their centrifugal force multiplied by the sine of the crank-angle. Working out these values and combining the action of both cranks, the Author has obtained curve No. 2, *Fig. 6.* Curve No. 3 is the resultant of curves Nos. 1 and 2, and shows the excess vertical action at the axle.

This, however, is not the only force which tends to give the engine an up-and-down movement. The obliquity of the connecting-rod causes a pressure on the slide-bars, which acts upwards during forward running, and which equals the total

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pressure on the crosshead, multiplied by the tangent of the angle which the connecting-rod makes with the axis of the cylinder. To get the total pressure on the crosshead, it is necessary to take the steam-pressure on the piston, and add to, or subtract from, it the additional pressure caused by the retardation or acceleration of the reciprocating parts. Since this disturbing force is not a constant quantity, but varies with the steam-pressure, the cut-off, and the speed of the engine, it has been thought useless to show its effect in modifying the vertical disturbances on *Fig. 6*. The excess vertical force of the two balances, together with this vertical action on the slide-bars, through being greatest first on one side and then on the other, causes a rolling motion of the engine from side to side. At the same time the upward pressure on the slide-bars, continually changing in magnitude, imparts a galloping movement to the locomotive, round the axle of the driving-wheels.

Hitherto the engine has been considered as running with steam on. But whether it is on or off does not alter the fore-and-aft disturbance. It does, however, affect the sinuous motion, since when the steam is shut off, the piston, instead of being moved by it, is alternately pushed and pulled by the crank. Thus the disturbing forces are made to act at the axle instead of at the cylinders, and have consequently more power over the mass of the engine. This explains the fact that engines run more steadily with steam on at high speeds. From the fact that the crank-axle is moving the piston instead of being moved by it, when steam is shut off, it follows that the pressures on the slide-bars, caused by the acceleration and retardation of the reciprocating parts, also change their direction from upwards to downwards, and this modifies the rolling and galloping of the engine.

In this Paper it has throughout been assumed that the horizontal forces are the most injurious to the stability of the locomotive. Some engineers in America consider the vertical disturbances to be the most harmful, principally on account of their effect on the rails and bridges, and balance their engines accordingly by not taking into account the action of the reciprocating parts.[1]

In England the majority of the locomotive superintendents aim at the mean between excessive vertical action on the one hand, and horizontal on the other, by only balancing part of the disturbance caused by the reciprocating parts.

[1] Transactions of the American Society of Mechanical Engineers, vol. ii. p. 274; American Institute of Mining Engineers, vol. ix. p. 375; *Railway Engineer*, July 1890, p. 174; November 1889, p. 339.

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The Author's reason for regarding the horizontal disturbances as the most destructive is that, whereas the vertical forces act on and are taken up by the springs, the horizontal disturbances act through the axle, axle-boxes and horns, and are thence transmitted to every part of the engine and its connections with the tender and train. He believes that by balancing them as far as possible, the saving in coal, and the reduction of wear and tear, would more than compensate for the increased cost of turning up the tires which would be made necessary by the excess vertical action. No doubt this would not be the case in America, where the weight of the moving parts frequently exceeds 2,000 lbs., and it would be quite impossible to fully balance the longitudinal disturbances, with due regard to the safe running of the engine.

In conclusion, the Author desires to express his thanks to the Locomotive Superintendents of all the principal railways who have given him every information as to the rules they use for balancing their engines, and to Mr. C. G. Crump, of the Record Office, for checking much of his mathematical working.

The Paper is accompanied by two tracings from which *Figs. 1* to *9* have been prepared.

[APPENDIXES.

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APPENDIXES.

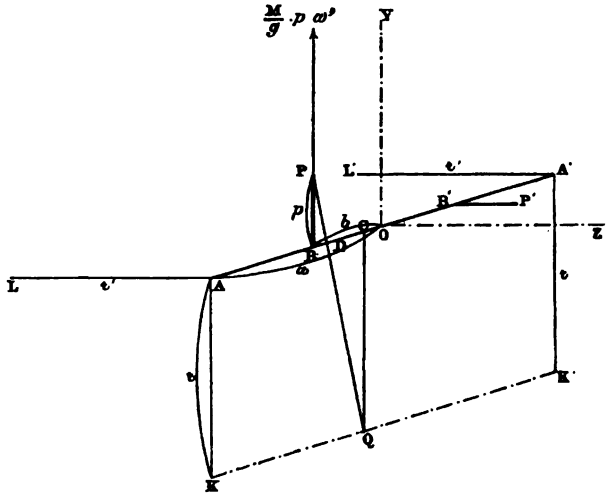
APPENDIX I.

THEORY OF THE METHOD OF BALANCING AN INSIDE-CYLINDER SINGLE ENGINE.

A A′ is an axle, of which O is the centre.
B P = p, and B′ P′ = p', are the two cranks.
B O = b = distance from the centre of the engine to the centre of the cylinder.
A O = a = distance from the centre of the engine to the centre of the wheel.
A K = r = distance from the centre of the axle to the centre of gravity of the balance-weight.

Let a weight of M lbs., fixed to P, represent that of the moving parts referred to the crank-pin.

Fig. 7.



[3] The force on the crank B P affects each wheel in proportion to its distance from the line of action, and must be met, in order to neutralize its effect on the engine, by other weights opposite it, one in each wheel, viz., at K and K′.

In like manner two weights must be placed opposite the other crank B′ P′, one at L and the other at L′.

Let ω be the angular velocity of the axle. Now the weight at P is M lbs., and therefore the centrifugal force at B is $\frac{M p \omega^2}{g}$ acting along B P. Let μ and μ' be the weights to be placed at K and K′. Then the centrifugal forces

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due to these are similarly: $\frac{\mu r \omega^2}{g}$, and $\frac{\mu' r \omega^2}{g}$ acting along A K and A K'.

The first condition which must be satisfied is that these forces must be in equilibrium, *i.e.*, the sum of their moments round O must vanish.

$$\text{Thus: } \frac{\mu r \omega^2}{g} \cdot a - \frac{\mu' r \omega^2}{g} \cdot a - \frac{M p \omega^2}{g} \cdot b = 0;$$

$$\text{i.e. } \mu r a - \mu' r a - M p b = 0;$$

$$\text{or } \mu - \mu' = M \cdot \frac{b p}{a r} \quad \ldots\ldots\ldots \quad (1.)$$

Again, the centre of gravity of these weights must be on A A'. Now the centre of gravity of μ and μ' lies somewhere along K K', say, at Q.

Let Q C be drawn perpendicular to A A', and let P Q be joined, cutting A A' in D. Now the force acting at P is M, and that at Q is $\mu + \mu'$. But the centre of gravity must be at D, and this will be the case if $M : \mu + \mu' :: DQ : PD$. But $DQ : PD :: r : p$, so that—

$$\frac{M}{\mu + \mu'} = \frac{r}{p} \text{ or } \mu + \mu' = M \cdot \frac{p}{r} \quad \ldots\ldots\ldots \quad (2.)$$

$$\text{But } \mu - \mu' = M \cdot \frac{b p}{a r} \quad \ldots\ldots\ldots \quad (1.)$$

$$\text{therefore } 2\mu = M \cdot \frac{p}{r}\left(1 + \frac{b}{a}\right);$$

$$\text{and } \mu = M \cdot \frac{p}{2r}\left(\frac{a+b}{a}\right) \quad \ldots\ldots \quad \text{I;}$$

$$\text{and } \mu' = M \cdot \frac{p}{2r}\left(\frac{a-b}{a}\right) \quad \ldots\ldots \quad \text{II.}$$

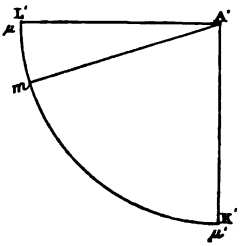
Now it is clear that there will be a weight μ' acting at K', and another μ acting at K, and similarly for the other crank μ' at L, at μ at L'. But μ and μ' may be replaced by a weight m which will have the same effect

$$\text{if } m = \sqrt{\mu^2 + \mu'^2} \quad \ldots\ldots\ldots \quad \text{III,}$$

$$\text{and if } \frac{\mu'}{\mu} = \tan\theta \quad \ldots\ldots\ldots \quad \text{IV,}$$

where θ is the angle which μ makes with its own crank, diverging from it towards the off crank (*Fig. 8*).

Fig. 8.



When this is done for both sides of the engine, each balance-weight will diverge from its own crank towards the other, so that the angle between the two will be less than 90°.

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Balance-Weights for the Engine under Consideration.

	Lbs.
Weight of the revolving parts referred to the crank-pin . .	= 680
Weight of the reciprocating parts referred to the crank-pin .	= 500
Total weight	= 1,180

Dimensions. (See page 281.)

	Inches.
a	= 30
b	= 12
p	= 12
r	= 33

By equation I . . . . $\mu = 1{,}180 \cdot \frac{12}{66} \cdot \frac{30+12}{30} = 300{\cdot}36$ lbs.

„ „ II . . . . $\mu' = 1{,}180 \cdot \frac{12}{66} \cdot \frac{30-12}{30} = 128{\cdot}72$ „

„ „ III . . . . $m = \sqrt{300{\cdot}36^2 + 128{\cdot}72^2} = 326{\cdot}7$ „

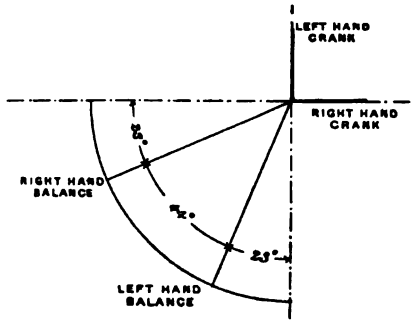
Inclination of Balance.

By equation IV . . . . . $\frac{128{\cdot}72}{300{\cdot}36} = 0{\cdot}429 = \text{tangent } \theta$,

$\theta = 23°$ approximately.

Thus the balance is placed at an angle of 23° with the near crank, diverging from it towards the off crank. The two weights are situated as in *Fig. 9.*

Fig. 9.



For an outside-cylinder engine the same rule may be used, but in this case the angle which the two balance-weights make with each other is greater than a right angle. For a coupled engine the disturbing parts may first be balanced as if they were not coupled; then the same may be done with the side rods, and the one result subtracted from the other.

N.B.—This only holds good when the outside cranks are opposite the inside cranks. When the two cranks are on the same side of the axle, the side-rods have to be balanced.

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APPENDIX II.

It has been shown in this Paper, in the section relating to the history of balancing, that many plans have been invented of having two cylinders on each side of the engine, and at the same end, the action of one of which should neutralize that of the other.

An important point seems to have been overlooked, viz., the effect produced by the finite length of the connecting-rod. If both connecting-rods were infinitely long, and the cranks 180° apart, the action on the one would counteract that on the other, as the disturbances caused by each would be the same at every point, whereas one would be positive while the other was negative. The separate effect of each would be represented by curve No. 1, *Fig. 1.*

But on taking into account the extra disturbances shown on curve No. 2, *Fig. 1*, which are those caused by the finite length of the connecting-rod, it will be seen that, instead of being neutralized, they are doubled, since the disturbances caused by each crank are the same at every point, and with the same signs also. This objection only applies to those engines like Haswells, where the cylinders are on the same side of the axle.

The following Table shows the effect of placing two cylinders side by side with cranks 180° apart:

Infinite Connecting-rod. Values of cos θ				Finite Connecting-rod, ratio 6·5 : 1. Values of $\frac{n^2(\cos^2\theta - \sin^2\theta) + \sin^4\theta}{(n^2 - \sin^2\theta)^{\frac{3}{2}}}$		
Crank Angle.	First Crank.	Second Crank.	Resultant.	First Crank.	Second Crank.	Resultant.
0	+1·000	−1·000	0	+0·1538	+0·1538	+0·3076
18	+0·951	−0·951	0	+0·1245	+0·1245	+0·249
36	+0·809	−0·809	0	+0·0485	+0·0485	+0·097
54	+0·588	−0·588	0	−0·0445	−0·0445	−0·089
72	+0·309	−0·309	0	−0·1281	−0·1281	−0·2562
90	0·000	0·000	0	−0·1633	−0·1633	−0·3266

As regards lateral movements, it will be observed that the disturbance due to the obliquity of the connecting-rod disappears, while that caused by the centrifugal force × cos θ is doubled. But as the cylinder centres will be very close together, and therefore nearly equidistant from the centre of the axle, these disturbances will not be at all large.

It is often claimed that an engine with three cranks, 120° apart, will be perfectly balanced. This would be the case, longitudinally, if the connecting-rod were of infinite length. But taking successive values of the complete formula

$$\cos\theta + \frac{n^2(\cos^2\theta - \sin^2\theta) + \sin^4\theta}{(n^2 - \sin^2\theta)^{\frac{3}{2}}}$$

for each crank, and combining the three, it will be found that the longitudinal disturbances, though not entirely destroyed, are much reduced, while on the other hand the sinuous disturbances are very bad indeed.

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APPENDIX III.

It will be noticed that while the longitudinal disturbances are almost entirely destroyed by this method of balancing, the transverse disturbances are not reduced in a corresponding degree. This is due to the finite length of the connecting-rod. The movements caused by the revolving parts are completely neutralized, but those due to the reciprocating parts, which are equal to their centrifugal force multiplied by the corresponding value of :—

$$\left\{\cos\theta + \frac{n^2(\cos^2\theta - \sin^2\theta) + \sin^4\theta}{(n^2 - \sin^2\theta)^{\frac{3}{2}}}\right\}$$

are left partly unbalanced.

If the connecting-rod were of infinite length, the disturbance would equal the centrifugal force $\times \cos\theta$. Hence the centrifugal force $\times$ the value of the second term of the above expression gives the extra disturbance caused by the finite length of the connecting-rod. This cannot be counteracted by a balance-weight, the compensating force of which necessarily varies with $\cos\theta$.

Thus the disturbing force left over is, for one cylinder : —

$$\text{W. R. N}^2\, 0{\cdot}00034 \times \frac{n^2(\cos^2\theta - \sin^2\theta) + \sin^4\theta}{(n^2 - \sin^2\theta)^{\frac{3}{2}}}$$

and for the other cylinder, whose crank is 90° behind :—

$$\text{W. R. N}^2\, 0{\cdot}00034 \times \frac{n^2(\sin^2\theta - \cos^2\theta) + \cos^4\theta}{(n^2 - \cos^2\theta)^{\frac{3}{2}}}$$

Working out these values for successive crank-angles, and combining those due to both cylinders, it is found that with one crank 90° behind the other, the longitudinal disturbance is nearly destroyed, but at the same time a couple is left which increases the transverse disturbances.

Right-Hand Crank Angle.	Value for R. H. Crank.	Value for L. H. Crank.	Resultant Longitudinal.	Resultant Sinuous.
0°	+0·1538	−0·1633	−0·0095	0·3171 Left.
18°	+0·1249	−0·1255	−0·0006	0·2504 ,,
36°	+0·0485	−0·0445	+0·004	0·093 ,,
54°	−0·0445	+0·0485	+0·004	0·093 Right.
72°	−0·1255	+0·1249	−0·0006	0·2504 ,,
90°	−0·1633	+0·1538	−0·0095	0·3171 ,,

These resultant longitudinal values, multiplied by the centrifugal force of the reciprocating parts, give the disturbance that is left after the engine has been balanced by the preceding method.

With regard to lateral equilibrium, it will be seen from the last column of the above Table that a couple is formed ; for example, when the right-hand crank angle = 0°, there is a force = 9,807 lbs. × 0·1538 pushing the head of the engine to the left, and a force = 9,807 lbs. × 0·1633 pulling it also in the same direction.

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The leverage of the couple is 1 foot, as the centres of the cylinders are two feet apart.

Hence the total force at this point is 9,807 lbs. × 0·3171, turning the head of the engine to the left (*vide* curve 2, *Fig. 3*). The product of the centrifugal force of the reciprocating parts, and the successive values of this couple, gives the unbalanced sinuous force on the engine.

APPENDIX IV.

The Effect of the Steam on the Disturbances of a Locomotive.

Mr. Robert Stephenson, in his evidence before the Gauge Commissioners in 1845,[1] being asked whether he did not think that outside cylinders caused more disturbance than inside cylinders, through the alternate action of the piston, replied :—

"It is exceedingly difficult to say; I cannot make up my mind about it. If you consider the action of the cylinder, it is perfectly rigid metal—engine and cylinder together. Now when the steam presses upon the piston, it is at the same time pressing against the lid of the cylinder; the action and re-action must be equal. Therefore, I do not believe that it is the steam that causes the irregular action, but I believe it to be the mere weight of the pistons themselves; and therefore, if we could continue to balance the pistons by the weight upon the wheel, we should get rid of that very much."

The opinion that an engine can be balanced by means of a suitable amount of compression, is still held by some. The following considerations, taken in conjunction with those quoted above, seem conclusive against it. The disturbances are caused by two things—the weight of the moving parts, and their speed. The weight is a constant quantity. Hence, in order to lessen the amount of the disturbance, the compression in the cylinder would have to be such, that it would reduce the velocity of the moving parts, and, therefore, of the driving-wheel, and would thus introduce an irregularity in the speed of the train which is the very thing that it is desirable to avoid. The due regulation of the compression of steam in the cylinders is equally important with the balancing; but the object of it is, in the Author's opinion, entirely different, namely, to equalize the effort on the crank-pin. He has therefore omitted the consideration of it from the Paper, as being really a separate branch of the subject.

[1] Report of the Gauge Commissioners. Carriages. Questions Nos. 246–7.

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OBITUARY.

GRANVILLE GEORGE LEVESON-GOWER, second Earl Granville, was born on the 11th of May, 1815. It is unnecessary in this place to enlarge on his political career as a leading member of successive Liberal Administrations since 1841. It will suffice to record that he was an *attaché* of the British Embassy in Paris during part of 1835 and 1836, and in the latter year was elected Member of Parliament for Morpeth, a seat which he soon afterwards exchanged for Lichfield. He was Under-Secretary for Foreign Affairs in 1840–1. In 1846 he was called to the House of Lords on the death of his father, the first Earl. From 1846 to 1848 he held the office of Master of the Buckhounds; from 1848 to 1851, that of Vice-President of the Board of Trade. In 1851–52 he was Secretary of State for Foreign Affairs; in 1852–54, 1855–58, and 1859–66, President of the Council; in 1868–70 he was Secretary for the Colonies; from 1870 to 1874, and from 1880 to 1885 he was again Foreign Secretary, and for six months in 1886 again Colonial Secretary. He was also an Elder Brother of the Trinity House, Chancellor of the University of London, and from 1865 to the time of his death, Lord Warden of the Cinque Ports.

Lord Granville's association with this Institution began in the year 1865, when he first attended the Annual Dinner, being invited officially as a member of the Government of the day. He afterwards accepted the Council's invitation on no less than eight occasions, being present in 1867, 1869, 1870, 1874, 1878, 1884, 1886, and 1890. At all of these banquets he manifested his goodwill to Engineers by making speeches couched in the most appreciative strain. It mostly happened that he had to return thanks for the Government, a function which he fulfilled with all the gracefulness and tact for which he was renowned, taking care that in a non-political assembly there should be no note of gratulation likely to offend those of opposite opinions to his own. Occasionally he spoke for the Upper House, notably in 1890. It happened that Lord Rosebery, being of senior creation, was deputed to return thanks for the House of Lords, but he flatly refused to do so in the presence of the older peer. Lord

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Granville, thus called upon, made, on the spur of the moment, one of his happiest efforts. With singular felicity, he disclaimed disinterestedness in his praise of engineers on the score of his association with them as an individual whose business it was to dig out coal and ironstone, and to make iron and steel for their consumption. At previous dinners he had claimed fellowship with the exponents of engineering science, and in 1881 it was thought well to mark the sense entertained by the Institution of his Lordship's genial overtures by nominating him as an honorary member. His certificate bears date the 6th of December, 1881, and after reciting his titles and honours, details his having filled the office of Vice-President of the Royal Commission for the Great Exhibition of 1851, his Chancellorship of the London University, his Chairmanship of the Commissioners of the Exhibition of 1862, and lastly, his interest in the production of iron, and his great and varied accomplishments, as qualifying him to be elected. It is needless to say of so courteous a gentleman as Lord Granville that he gracefully accepted the honour, and duly fulfilled the prescribed formalities attendant on his election. Owing to his Staffordshire estates largely producing coal and ironstone, which latter was worked up in his own furnaces, Lord Granville was intimately connected with the iron-making industry of the country, which no doubt disposed him to take an active interest in the objects for which this Institution was established. In any case, he occupied a unique position among its Honorary Members, and one that is not likely to be easily refilled.

Lord Granville died on the 31st of March, 1891, in his seventy-sixth year.

STEPHEN BALLARD was born on the 5th of April, 1804, at Malvern Link. His father, Mr. Phillip Ballard, was a solicitor. After the usual term of schooling, which in that day was not of a wide range, his tastes led him to the congenial occupation of a nurseryman, and for some years he was with Messrs. Lee and Kennedy, of Hammersmith. Leaving this calling, he determined to learn building, and apprenticed himself for three years to Mr. Lucy, of Cheltenham, who afterwards worked for Mr. Ballard when the latter had become a large employer of labour. He then became, through the influence of Mr. Biddulph, the grandfather of Mr. M.

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Biddulph, M.P., manager, and afterwards engineer, of the Hereford and Gloucester Canal, and carried out the extensions of the same between Ledbury and Hereford. On the completion of that work Mr. Ballard was appointed Resident Engineer by Messrs. Walker & Burges of the Middle Level Main Drain. This work was carried out under his supervision from the Ouse to the junction with the sixteen-foot river at Upwell. It was when this was on the point of completion that he was introduced to Mr. Brassey, whom he met accidentally at the Cambridge railway station. Mr. Brassey, who had contracted for the making of the Great Northern Railway between London and Peterborough, was returning to London from a visit of inspection to the country through which the line was to pass—a portion of the land being a "quaking bog." On consulting one of his trusted agents as to this difficulty, the agent said, "Ask Mr. Ballard; he has had considerable experience in the Fens." Mr. Ballard became Mr. Brassey's principal agent for carrying out the works of the Huntingdon district, extending from Biggleswade to Peterborough, upon which section occurred by far the most difficult part of the line, the railway traversing the Fen country. The method adopted by him was to build up gradually a kind of solid raft, formed of alternate layers of faggots and peat sods, the effect being to displace the water, but to leave the solid parts behind. Great stress was laid by Mr. Ballard on the necessity, in all such cases, of proceeding slowly, adding the weight little by little, so as to allow the water time to escape.

In 1851 he went to India to inspect the country for a line of railway; but his stay was confined to a few months, the climate not agreeing with him. In 1852, in conjunction with Mr. Brassey, Mr. Ballard undertook the construction of two sections of the Dutch Rhenish Railway between Utrecht and Rotterdam and between Arnheim and the Prussian frontier. A great portion of the line—between Utrecht and Rotterdam—was over peat similar to that of the Fen district of the Great Northern Railway, and was successfully executed by Mr. Ballard in the manner there adopted.

His next work was the Worcester and Hereford Railway. His efforts to promote this undertaking exhibited him in an unusual light. In the early days of railways, the companies had to contend with the greed of landowners, and fabulous sums were often demanded for land of little value. When Mr. Ballard was applied to for a part of his land, which was required for the line, his answer was, "Take it at your own price"; and to those who

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feared that his generosity might be to their pecuniary disadvantage, he declared that so sure was he of the benefit that would ultimately accrue to all by its construction, that he would not hesitate to make a present of his land rather than that the project should not be carried out.

The Ashchurch and Evesham Railway next engagedMr. Ballard's labour, in 1862, and in 1864 the Evesham and Redditch line, both of which made heavy demands on his strength and patience without corresponding profit. But it was a principle with Mr. Ballard first to discharge his obligations, not allowing the risk of loss to interfere with his sense of honour. His last undertaking was the extension of the Midland Railway from Bedford to London, which was commenced in 1865.

Perhaps no employer was ever regarded with more real respect and affection by his workmen. They felt that their master was a friend in whom they could place implicit trust. Numbers of the old employees would from time to time call at Mr. Ballard's house, The Winnings, some in less prosperous circumstances than aforetime, but many who had attained positions of ease and comfort by their industry and sobriety. They never called without receiving a hearty greeting, and thoughtful help when help was needed. A pleasing incident illustrative of this reciprocity of kindly feeling transpired only recently. Mr. Ballard took with him to Holland, in 1852, a number of workmen. One of them was offered a permanent situation on the completion of the railway, which he accepted. After the lapse of thirty-eight years the man made a journey from Holland to Colwall to see his old master. This is but a solitary instance of the cementing influence which a generous and true-hearted employer exercised on material not the most easily wrought upon.

He purchased and settled on the appropriately-named Winnings estate about forty years ago, erecting his own and several other handsome residences upon it. His model farm buildings have been copied in many places. The village and neighbourhood of Colwall has undergone a variety of improvements through Mr. Ballard's instrumentality. Ten years ago he built a Workmen's Hall and Temperance Hotel, and he has carried on a successful vinegar manufactory. The "Jubilee Drive," which is a fine road along the upper side of the Malvern Hill, a welcome alternative to the old highway at the base of it, will long be associated with his memory. He was not only the prime mover in this enterprise and the largest subscriber, but gave a considerable portion of the land, and superintended the whole of the work.

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One incident, characteristic of his nature, may be mentioned here. It became necessary to banish a number of starlings, which had fixed their nests about the mansion, at The Winnings. Mr. Ballard built a bird-house for them in the grounds, and so suitably did it meet their tastes that they removed to it of their own accord.

Four Papers from his pen have appeared in the Minutes of Proceedings,[1] and not many weeks before his death he brought out a second edition of his pamphlet on "Cheap Railways," in which he advocated the construction of light lines in many places where the ordinary heavy system would not be profitable. This idea is bearing good fruit in Ireland. He was a geologist, and was very fond of botany, and a horticultural show has been regularly held on one of his meadows. At the model farm-buildings he presided every autumn over one of the most enjoyable "harvest homes" that could be conceived. In consequence of his serious illness, last autumn passed by without the usual festivities.

He died on the 14th of November, 1890, in the eighty-seventh year of his age. According to his expressed desire, he was interred in a steined grave made on the top of a high mound formed with the soil from the boring of the Malvern railway tunnel. This tump is about 300 yards from The Winnings residence, and approached by a road known as "Ballard's Drive," leading to the Malvern Hills. A few yards from the grave is the third ventilating shaft of the railway tunnel. It is almost exactly in the centre of the estate, near to the field in which the flower shows have taken place, and in view of handsome plantations of trees, in the culture of which Mr. Ballard took such delight.

Mr. Ballard was elected an Associate of the Institution on the 14th of March, 1837, and was transferred to the class of Member on the 17th of February, 1846.

JOHN GEORGE THORNTON CODDINGTON, second son of the Rev. Henry Coddington, Vicar of Ware, Herts, late Fellow of Trinity College, Cambridge, was born on the 29th of June, 1841, at the Vicarage, Ware. He was educated at Charterhouse School, and also received private tuition. He went as pupil to Sir John Macneill in 1858, and in 1860 was sent to Londonderry to lay out and superintend the construction of the Lough Swilly Railway. Subsequently he prepared Parliamentary and

[1] Minutes of Proceedings Inst. C.E., vol. i. (1839), pp. 31, 52, vol. i. (1838), p. 47; vol. x., p. 352.

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contract plans of the Buncrana Branch, and took the soundings for a pier in Lough Swilly. He remained as Resident Engineer under Sir John Macneill till 1865, when all these works were completed and opened for traffic. In 1866 and 1867 he was employed making surveys and setting out railways in England and Ireland.

Early in 1868 Mr. Coddington proceeded to India under a five years' covenant with the Government. He was posted to the Irrigation Department of the North Western Provinces, and in this branch he served till his resignation in 1879. After a short period of secretariat duty he held charge of the Survey for the Fatehgarh Branch of the Lower Ganges Canal. This work involved about 1,000 miles of levelling over a country where there was little to guide the eye, and where at the same time an error in location would have serious consequences. The resulting project was distinguished for extreme accuracy in levelling and comprehensive location and scope. On the commencement of the construction of the Lower Ganges Canal, in 1872, Mr. Coddington was placed in charge of the Third or Bhongaon Division of it as Executive Engineer. This appointment he held for about four years, during which time the alignment of the canal, nearly the whole of the extensive excavations and collection of material, and the construction of four large bridges—two of them on the skew—were carried out under his superintendence. Here Mr. Coddington received the acknowledgments of the Government for his success. He was distinguished for love of accuracy, completeness, and economy, and by his zeal for obtaining only the highest class of materials and workmanship.

After a period of furlough he rejoined the Lower Ganges Canal in 1878, this time as Executive Engineer of the second or Kharganj Division. Just then a famine and epidemic of fever supervened on the failure of the monsoon rains of 1877, and there was great anxiety for the pushing on of the canal distributaries, both as relief works and for giving a supply of water to the land. Into his duties Mr. Coddington entered with characteristic devotion, and under his superintendence 55 miles of the distributary irrigating channels of the Fatehgarh branch were lined out and prepared ready to receive the water between June and December, 1878. For this work he received the special thanks of Government; but the anxiety and worry were too much for his health. His friends prevailed on him to retire in 1879, the Government giving him a handsome bonus and a pension.

After some time spent in travelling in Germany and Italy,

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having regained his health, he went in 1883 to Ireland to make plans and surveys, &c., for light railways, and in November, 1885, was elected Engineer-in-Chief of the Suck Drainage Board, in which employment he continued to the end of his life. The Suck Drainage dragged on for years without useful result for money expended, until Mr. Coddington put new life and sound engineering into the project.

Mr. Coddington died on the 11th of March, 1891. He was elected a Member of the Institution on the 1st of May, 1877. Many of his brother officers in India regret the genial host, the accomplished musician, and the kindly companion, who has passed away.

ROBERT JOSEPH HUTTON was born in Dublin on the 22nd of April, 1842. He was educated at Portora Endowed School near Enniskillen, then perhaps the chief school in Ireland. In the summer of 1858 he entered Trinity College, Dublin, where he obtained a mathematical scholarship in 1861. He graduated at Michaelmas, 1862, receiving the First Gold Medal for Mathematics, in which he was bracketed equal with the late Lord Chancellor Naish, and the First Silver Medal in Experimental and Natural Science. For the next four years he served a pupilage under Messrs. B. and E. Blyth, of Edinburgh. During the summer of 1868 he was employed as Assistant Engineer by Mr. James Barton, on the Carlingford Bar Works. From May, 1869, to March, 1872, he was on the Dundalk and Greenore Railway as Resident Engineer during its construction, also for Mr. Barton. From March, 1872, to 1873, he was employed by the Irish North-Western Railway Company as Engineer of the northern half of the line from Enniskillen to Londonderry and Bundoran, a length of about 100 miles.

From 1873 to 1874 he had charge as Resident Engineer of the doubling of the Whitehaven line, Furness Railway, and of the Arnside branch for Mr. F. C. Stileman. From 1874 to 1878 he was engaged as Assistant Engineer on the loop-line of the Cape Government Railways under Mr. W. G. Brounger, and was also at the same time Resident Engineer of the Orange River Bridges for Mr. James Fforde. After his return from the Cape he was induced to put his money into a large brick works near Cork, of which he took the superintendence. Owing to the depressed condition of affairs in Ireland at the time, he lost all, and had to begin again

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as a Resident Engineer under Mr. Barton on the Cloghen Valley Railway. On the completion of that line he went to the Argentine Republic, where he was engaged on various railways as contractor's engineer.

He died on the 11th of September, 1890, suddenly, of hæmorrhage of the brain, at a hotel in Tigre, about 3 miles from Buenos Ayres.

Those who knew him best bear testimony to the sincerity and simplicity of his character: truthful and candid in disposition, and with a high sense of duty, he was intolerant of anything approaching what he considered hypocrisy, and some of the difficulties of his career are perhaps to be ascribed to his inability to bend his mind to take the views of others. He was elected an Associate of the Institution on the 1st of April, 1873, and was transferred to the class of Member on the 11th of May, 1880.

ALEXANDER MACNAB was born at Belleville, Ontario, on the 18th of March, 1837—a memorable year in Canada, owing to the outbreak of the Canadian rebellion, in which his father, Captain James Macnab, was killed in the performance of his duty to the loyalist cause.

Mr. Macnab began his professional career in 1853, and was engaged for two years in the construction of the Hamilton and Toronto Railway under Mr. Marcus Smith. He then joined the engineering staff of the Great Western Railway of Canada, at that time in course of construction, and now forming part of the Grand Trunk, and was connected with this line for five years under Mr. George Lowe Reid. In 1861 he received from the Imperial Government the appointment of Surveyor of Public Works in the Island of Granada, West Indies, but was compelled to resign after a few months on account of ill health.

In 1865 he assumed the office of Chief Engineer to the Government of the Province of Nova Scotia, having charge of the construction and maintenance of the railways built by that Government. In 1872 he received the additional appointment of Chief Engineer of the Maintenance of Way Department of the Intercolonial Railway, about 750 miles in length, connecting the maritime provinces with Canada; and this position he held until, in 1878, he came to England for the benefit of his health. On his return to Canada he undertook the management, engineering

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and otherwise, of the Prince Edward Island Railway, which, however, after two years, proved too great a strain, and he was obliged again to take a rest for the sake of his health.

For the next ten years he lived in England, and in May, 1887, became Chief Engineer to the late Mr. T. A. Walker, in connection with the heavy contracts that gentleman then had on hand, consisting of the Barry Dock and Railways, the Buenos Ayres Harbour Works, the Preston Docks, and the Manchester Ship Canal. Early in 1888 he went out to Buenos Ayres to inspect the Harbour Works, but during the last two years his attention was chiefly confined to the Manchester Ship Canal; and it was while engaged on this contract that he was taken ill at Manchester, and after lingering nearly six weeks, died on the 4th of January, 1891.

Mr. Macnab was endowed with a most amiable disposition and attractive manner, and was beloved by all with whom he had relations, either social or professional. His character was a noble one, and his zeal and faithfulness to the interests entrusted to his care won for him the esteem and confidence of all who had to do with him.

He was elected a Member of the Institution on the 3rd of December, 1878.

WILLIAM RUSS, came of an old Hampshire family, which has been settled in the neighbourhood of Winchester for many generations. He was in 1848 a pupil to Mr. Sharp, Gas Engineer, of Winchester and Southampton. He then went to Australia, and in 1851 and 1852 was on the staff for the survey of Crown lands, roads, and bridges in the Colony of Victoria. He afterwards acted for several years as Resident Engineer of the South Essex Waterworks, in the employment of Messrs. Easton & Amos. He then entered into partnership with Mr. Charles Minns, in conjunction with whom he carried out the sewerage and drainage and water supply of a number of towns, amongst which may be mentioned Romford, Ware, Brentwood, Sawbridgeworth, Enfield, Andover, Swindon, Shirehampton, Westbury-on-Trym, Stoke Bishop, Portishead, Basingstoke, Newport (Isle of Wight), Richmond (Surrey), and Petersham.

He was also extensively engaged in the reclamation of land from the sea in Essex, Norfolk, and Hampshire. He designed a scheme for bringing sea-water from Shoreham to London, for

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which an Act was obtained in 1881, and was also engaged in the designing of the Mid Kent Water-works and the Guernsey Water-works. In common with his brother, Mr. Percy Russ, he paid great attention to the subject of fish-culture, and wrote several reports on the cultivation of oysters.

He was well known and respected at the offices of the Local Government Board, with the officials of which he was constantly in communication in connection with inquiries in relation to various sanitary works.

Mr. Russ was an enthusiastic Volunteer, and besides holding a commission in the Guernsey Militia, belonged in succession to the 1st Hants Volunteers and the 3rd Essex Rifles, from which latter corps he retired with the rank of Major. He is regretted by a large circle of friends, to whom he had endeared himself by his geniality of disposition, his kindliness of heart, and the sterling integrity of his character.

He died, in his 63rd year, after an illness of only a few days, on the 13th of February, 1891. He was elected a Member of the Institution on the 3rd of December, 1878.

MICHAEL SCOTT was born in Glasgow on the 4th August, 1818. He was educated at Fisher's Academy, and afterwards attended the lectures of Professors Graham, Wilson, and Gregory, at Anderson's College, Glasgow, where he distinguished himself for his regular attendance. He studied architectural and mechanical drawing with great interest, and became an excellent draughtsman. He soon evinced a taste for mechanical engineering and was anxious to learn the practice of it, and although the project was opposed by some members of his family, his mother wisely determined to encourage her son in his natural talents, and he was articled as a regular working apprentice. The firm to which he was first apprenticed appears to have given up business shortly afterwards, but he served a regular period of pupilage under Mr. Starke (Glasgow) as Mechanical Engineer, then on the Ayr Railway, and afterwards under Messrs. Caird & Co., Greenock, as a Marine Engineer.

During his apprentice days a threatened attack by his shopmates was prevented by the gate-keeper, a former shipmate in the Royal Navy of a servant of his father. Having only served three years, by the rules of the Trade Union he was not allowed to act

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as a journeyman, although the works manager had employed him in this capacity and given him the full wages. "Hey lad, hast thou lines?" asked the gate-keeper. "No," he replied. "Thou must up anchor and off," and he closed the gates against the excited workmen whilst Scott made good his retreat. An extract from his diary on his railway experience in those days is interesting. "Called at 5 A.M., started with break-down gang; engine had gone off the rails at a bridge, knocking over 20 feet of parapet, and was as near as possible over into river; returned to terminus. One o'clock message, another train off the line, gang sent—I remained; five o'clock, no news, another train past due, at last it arrived, had also been off the line; six o'clock train late, started with an engine to see what was wrong. Driver let fire low, steam down, stopped, expecting to be run into every minute; broke down a fence to burn and got steam up just in time to escape."

Referring to the Glasgow Post Office of those days he says, "It was a miserable little place, situated a little way up an alley branching off the main street. There was a little old man dressed in knee breeches, who had a little wheelbarrow, and suspended from his neck by a leathern strap was a large old-fashioned watch, the back resting on his breast, and the face exposed so that all could see the time. There was only one mail from the south in the day, and it was often late; when the coach arrived the little letter-bags were placed in the old man's wheelbarrow, the watch showing the time, and away he scuttled up the alley to the post office, the watch proving he had not loitered on the way."

At one time whilst engaged in the manufacture of engines, a trial was to be made, and the stoker had, unnoticed, hung the great weight intended as a balance for the damper upon the extreme end of the safety-valve lever. Addressing men near him he ordered two to remove the weight, and on their refusal, Scott undertook it himself, and succeeded in pushing it in a little distance; the lever instantly tipping up caused the weight to slide further inwards, thus relieving the pressure of the boiler. Mr. Scott said he lived a lifetime in those few moments.

Whilst studying shipbuilding and marine engineering, in order to gain maritime experience he took employment as an Assistant Engineer on one of the steamers between Glasgow and Liverpool in 1843. After his seafaring life terminated he moved south, where his headquarters continued ever after.

Soon after this an Assistant Engineer was wanted for the Bootle Water-works near Liverpool, and Mr. Scott applied for and obtained the appointment. In 1846 he became Engineer-in-Chief

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to the Company, and successfully completed the undertaking. When the Water-works were purchased by the Corporation of Liverpool in 1847, Mr. Scott was unanimously appointed Resident Engineer, and held that office till the end of 1849, when he proceeded to London and began business on his own account as a Civil Engineer. One of his first engagements was the superintendence as Resident Engineer of the construction of extensive harbour works at Goole, which he had designed. In 1851 he was consulted by the Corporation of Swansea in connection with the water-supply for that town, and the Bill authorizing the works recommended in his report received the Royal Assent on the 30th June, 1852. About this time he invented an apparatus for laying large masses of concrete under water, everything being done by divers.[1]

From 1856 to 1860 he was engaged as contractor under Mr. James Abernethy, in the construction of the Port of Blyth breakwater. On the 7th December, 1858, Mr. Scott read a Paper before the Institution describing this work, for which he was awarded a Telford medal.[2] In a supplementary Paper on the same subject read on May 22, 1860, he remarks that it had been exposed for four winters without injury. In connection with these works he read Papers before the Institution of Mechanical Engineers on a steam pile-driving machine, which was also available as a steam crab and a dredging machine. Whilst at Blyth he arranged a system of profit sharing, which worked satisfactorily, and is interesting as being one of the earliest instances of a profit-sharing concern in England. He described this system anonymously in 1866 in a pamphlet entitled: "On the relations between masters and men." In 1865 Mr. Scott was engaged in the construction of another breakwater at St. Ives in Cornwall; but the undertaking had to be abandoned as those locally interested in it were unable to obtain the capital required to complete it. In his capacity of Consulting Engineer he designed some important buildings constructed at Bombay, including the Victoria and Albert Museum there.

Having formed a high opinion of the Siemens open-hearth process of steel manufacture, he called upon some enterprising capitalists in Glasgow with a view to its being introduced as an

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[1] Report of the Commissioners on Harbours of Refuge. Vol. i. Folios 295, 298. London, 1858.

[2] Minutes of Proceedings Inst. C.E. vol. xviii. p. 42.

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industry into Scotland. In this he was successful and a Limited Liability Company was formed, of which he was appointed interim Secretary and General Manager. The works, which were built at Hallside, near Cambuslang in Lanarkshire, were erected on plans supplied by the late Sir William Siemens, and were carried out under Scott's directions in a perfect manner, but unfortunately for the immediate prospects of financial success, before they were ready to commence operations the prices of steel had begun to fall, and Mr. Scott was advised to refuse to accept contracts on a falling market. As he had already purchased stocks of pig-iron and ore at the inflated prices, the prospects of successful manufacture were very small, and it resulted in his resigning his position; this resignation was a great blow to him, but he felt, as did also his friends, that the fault was not his, but due to untoward circumstances. It may be added that the Steel Company of Scotland has now for years been a successful concern.

Mr. Scott was also concerned in other enterprises with which his name has not been directly connected. On the 8th July, 1858, a scheme of Dr. Siemens and Mr. Scott for the purification of the Thames appeared in the *Times* newspaper, similar to the one described by Mr. Scott in a letter dated 9th March, 1868, addressed to the Chief Magistrate of Glasgow, as applicable to the Clyde. It was proposed that at every tide a column of comparatively pure water should be so interposed as to prevent the reflux of the impure water with the returning tide and thus twice in twenty-four hours the sewage would be forced out to sea.

In 1860 a Committee of the House of Commons had under consideration the purification of the water of the Serpentine by filtration. Mr. Scott drew up a memorandum on the subject in which he stated that the chief stimulating cause of vegetation in water exposed to daylight was carbonic acid, either free or combined with certain bases in the form of salts, and proposed its removal by applying Dr. Clarke's process for softening water. On his recommendation, caustic lime was added to the water in the upper reach of the Serpentine with the result that it became and continued quite clear for some time.

He took great interest in matters connected with Naval Warfare and Defence, and read Papers on these and cognate subjects before the Royal United Service Institution, the Institution of Naval Architects, the British Association and elsewhere. In a speech at the meeting of the Royal United Service Institution of the 21st of May, 1862, he showed that for a given bore of gun, whatever the

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weight and velocity of the shot, provided they varied so as to keep the strain on the gun unaltered, the destructive power of the shot always remained the same. In his Paper on Projectiles before the same Institution, he described the accomplishment of what had previously been held to be impossible, viz., the firing from a smooth-bore gun of elongated projectiles which did not revolve, and which did not turn over during flight. He brought forward a plan for the defence of Spithead, in which he proposed to place two powerful forts in a position to bar the channels between the forts and shore, and provided means for impeding the passage of an enemy's vessels through the deep-water channel.

Mr. Scott commenced his professional career as a Marine Engineer, and a great portion of the 2nd volume of his "Occasional Papers" is devoted to Naval Architecture. He claimed to have originated and first made known the Inflexible type of ship. In the Inventions Exhibition he placed outline drawings of war-ships of types originated by him, of which the first plan was communicated officially to the Admiralty on 25th August, 1870, and the second was explained to the Chief Constructor in May 1871. The first plan included a central armoured citadel the full breadth of the ship, an armoured deck under water; the cellular system arranged so that fuel could be stowed in it, high freeboard, and guns protected by armour; in the second plan the armoured under-water deck was sloped downwards, so as to save weight, prevent the ship being raked in a sea-way, and strengthen the ram stem. He also proposed to place the turrets abreast, in order to obtain fire in the line of the keel both fore and aft from all the large guns in both turrets simultaneously, and to provide sail power without the disadvantages of rigging. Subsequently the "Inflexible" and other vessels were built, embodying several of these improvements. Mr. Scott's claim to have originated this type of ship was acknowledged by several Admiralty authorities, and Mr. Merrifield wrote to him: "I have always considered that you had priority in all that distinguishes the Inflexible type apart from a question about the unpublished sketches of Mr. Reed just before he left the Admiralty." The Admiralty, however, have not considered that Mr. Scott had any claim to compensation.

Those who knew Mr. Scott best will agree that the main reason why his professional career was not a marked success, was that his interests were so multifarious that he did not draw that distinct line between business and pleasure, which is necessary to ensure success. He was a very fair musician, and more than an average art critic; in his more prosperous days his house, which was

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replete with treasures of Art, was the rendezvous of its votaries. He was of a most kindly and amiable disposition, and was constantly engaged in works of benevolence done without ostentation. In his declining years, which he spent in Tunbridge Wells, he took great interest in local charitable institutions, especially those having reference to children. For some years previous to his death he was in delicate health and had practically retired from professional life. He died at Tunbridge Wells on the 13th of September 1890. He was elected an Associate of the Institution on the 1st of February 1848, and was transferred to the class of Member on the 26th of April, 1853.

JOHN LUM STOTHERT was born on the 29th of June, 1829, at Bath. His father was Mr. Henry Stothert, then proprietor of the old Newark Foundry at Bath. He received his education at private schools, and in 1845 was apprenticed to the firm of Stothert and Slaughter, at their locomotive works in Bristol, where, under Mr. Slaughter's somewhat strict but admirable rule, he acquired a thorough mastery of handicraft, and laid the foundation of that sound practical knowledge for which he was distinguished in after life.

In 1844 Mr. Stothert's father took into partnership his then managing engineer, Mr. Rayno, and also Mr. R. Pitt, who had served his apprenticeship at the works in Bath, the firm becoming Stothert, Rayno, and Pitt. Eight years afterwards Mr. Henry Stothert withdrew from active participation in the business, and transferred his share to his son, and on the retirement of Mr. Rayno in 1855, through ill-health, the firm became Stothert and Pitt, and the business was carried on under that title by the two partners for the succeeding thirty years. During this long period of hard and active labour Mr. Stothert earned a prominent position amongst mechanical engineers by the soundness of his designs and the careful manner in which they were carried out, so that in general engineering, and especially in the department of lifting-machinery, the reputation of the firm became second to none.

The part Mr. Stothert took in the introduction of machinery for making and dealing with artificial blocks of concrete for the construction of breakwaters and harbours is in too recent recollection to require detailed description here, but it may be said that in this particular branch his experience was without parallel.

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About the year 1883 his health, which up to that time had been apparently strong, showed signs of giving way, and his partner, Mr. R. Pitt, broke down a few months afterwards. This led to the formation of the present private company, Stothert and Pitt, Limited, of which Mr. Stothert remained chairman until his death, and was always ready with his counsel and experience although he retired from the active management.

Mr. Stothert was also for a time chairman of the Avonside Engine Company, Limited, the successors of the firm with whom he was brought up. He was a leading director of the Bath and Bristol Gas Companies, and also of other local companies, his energetic disposition never permitting him to be long without doing some useful work. Those who visited Bath during the British Association meeting in 1888, and who were in any way behind the scenes, will remember how admirably he filled the position of local secretary.

Mr. Stothert's favourite relaxation was found in his small but extremely well-fitted observatory, where he occupied himself with practical astronomy, of which he was very fond. He had also a well-furnished private workshop. His health had been in a very unsatisfactory condition for some years, and he died somewhat suddenly, from heart disease, on March 5th, 1891, amid the general regret of a large circle of friends. His character and abilities were such that most of those who commenced his acquaintance by formal business relations remained for years his personal friends. As an engineer he possessed the true instinct of "mechanical fitness," and an adaptability of resource which enabled him to deal successfully with problems outside the range even of his large experience. His early training in the best traditions of the old millwright school gave him a love for honest work which made him regard scamping with utter abhorrence, and contributed not a little to the confidence with which his friends looked forward to the completion of whatever he took in hand.

Mr. Stothert was a Freemason, and held high office. He was a member of the Grand Lodge, and in this connection actively participated in the charitable work of the society.

He was elected a Member of the Institution on the 4th of March, 1879.

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THOMAS WARING was born in 1825 at Wheatley Hall, Wooley, in the West Riding. After serving a regular period of pupilage as an Engineering Surveyor, he entered the office of Messrs. T. L. Gooch and F. M. Young, and was employed by them on the construction of the Leeds and Bradford and Extension Railways. This engagement having come to a close when all the works were completed, Mr. Waring became Contractor's Engineer under Mr. Young. He carried out contracts on the Leeds Waterworks extensions under Mr. J. W. Leather; on the London and North-Western Railway branches under Mr. Woodhouse; on the Furness Railway, and Ulverston and Lancashire Railway under Messrs. M'Clean and Stileman. He was also engaged on some arbitrations at Sunderland Docks and other places. In the autumn of 1854 Mr. Waring became Resident Engineer upon the Cardiff Sewage Works under Mr. Hawkshaw, and the office of Surveyor to the Local Board of Health of Cardiff falling vacant in the following year, that appointment was also offered to Mr. Waring. The carrying out of the Sewerage Works was not effected without some difficulty; the severe weather in 1855, together with financial difficulties, and the necessity of opposing a scheme which would have compelled the drainage of all Butetown into the packet slip, delayed the final completion, which was not effected till 1857. The beneficial effect of it, however, was speedily apparent in the improved health of the town. No sooner was the first sewage scheme finished than a material extension was required, which was successfully accomplished under Mr. Waring's directions. In a short time the length of the sewers had to be doubled in consequence of the rapid growth of the town. Many new streets were built, and the whole of the old ones re-made, and there are few public institutions in Cardiff which have not benefited in some way by Mr. Waring's exertions. The large expenditure of money in the erection of cottage dwellings for workmen, on land liberally granted by Lord Bute at a low rent, was in a great measure due to his influence. For several years he was Surveyor to the Canton and Roath Boards of Health, and Chief Engineer to the Cardiff Rural Authority. He acted as Engineer to the Borough of Aberavon, and laid out their system of sewerage and water supply. He took an active interest in municipal affairs, and in 1886 was elected Alderman.

Mr. Waring was a ready speaker, eminently practical, and always listened to, on account of his great experience, with attention. He was a Member of the Council of the University College

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of South Wales and Monmouthshire. He died on the 24th of April, 1891.

He was elected a Member of the Institution on the 1st of April, 1862.

ROBERT WATSON was born at Dartington, near Totnes, Devonshire, on the 21st of November, 1822. He was educated first at local schools, and subsequently at the Exeter Diocesan College. He then became articled pupil to the late Mr. Henry Symons, of Plymouth, and was connected with the construction of the South Devon Railway, and was also engaged, under the late Mr. Wm. Froude, on the Plymouth and Tavistock and the North Devon Railways. Between 1849 and 1851 he spent a year with an architect in London, and a year with a mechanical engineer, during which time he was connected with the erection of the Hanwell and the Warwick Lunatic Asylums. In 1852 he joined the staff of Messrs. Locke and Errington, with whom he was engaged on the Shrewsbury and Aberystwith and the Direct Portsmouth lines.

In November, 1854, he proceeded to Victoria, and on his arrival in Melbourne, almost immediately joined Mr. Darbyshire, Engineer of Construction, then District Surveyor under Government at Williamstown. There was at that time no Railway Department. The surveys were under the control of the Surveyor-General, Captain (now Sir Andrew) Clarke, and Mr. G. C. Darbyshire. His first work was to lay out the main road from Melbourne to Ballarat, with instructions to examine the country, having in view railway construction at some future time. The levels over this road were the first taken far into the country. The datum was an assumed low-water mark in Hobson's Bay, and the levels for the whole railway system of the colony have been reduced to it. On the completion of this preliminary work, the railway surveys were commenced, and Mr. Watson at once occupied a prominent position in connection with them. The Geelong and Ballarat Railway, the direct Ballarat line, the Echuca line, the North-Eastern and branches, the Gippsland line and branches, many of the lines to the Western District—in fact, all the principal railways of the colony—were surveyed under his direction, and it is a somewhat remarkable fact that the line from Bacchus Marsh to Ballan, now under construction, follows literally the route marked by him about thirty years ago, notably in the

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difficult part immediately after leaving Bacchus Marsh, where there is an abrupt ascent of 300 feet in a distance of less than a mile. Mr. Watson, as Resident Engineer, superintended the construction of the Geelong and Ballarat Railway, the Sandhurst and Echuca, the North-Eastern and branches, the Gippsland and branches, and many others.

Having carried out these works in a satisfactory manner, he was granted twelve months' leave of absence on account of ill health, and visited Europe, accompanied by his wife, who unfortunately died in England. On the expiration of his leave he returned to Melbourne and resumed work in the Railway Department. In 1878, when political emergency deprived the Government of the services of Mr. Thomas Higinbotham, Mr. Watson became Engineer-in-Chief. In 1880 a new Ministry expressed a wish to redress what had been regarded as a great injustice and wrong, by re-instating Mr. Thomas Higinbotham as Engineer-in-Chief. Mr. Watson was offered the position of Senior Resident Engineer, without any alteration in the salary he had been receiving, and his position was to be only temporary, as changes were contemplated which would make it possible for him to resume the office of Engineer-in-Chief. However, he elected to retire, and Mr. Higinbotham was re-instated. Shortly after other changes took place, and Mr. Watson was asked whether or not, in the event of Mr. Higinbotham's resigning, he would be willing to resume the position of Engineer-in-Chief. These overtures he unhesitatingly rejected as unjust and unfair towards Mr. Higinbotham.

Mr. Watson then went on a difficult expedition for the Queensland Government. He explored the country from the East Coast to the Gulf of Carpentaria, with a view to the construction of a railway, and received the highest praise for the manner in which he carried out the enterprise.

Unhappily, Mr. Higinbotham died suddenly, a few months after his re-instatement, and another Engineer-in-Chief was appointed in his place. Mr. Watson was asked in 1882 to return to his former position, which he held up to the time of his death.

To Mr. Watson is due the credit of introducing cheaply constructed railways, and timber bridges, altogether lighter and less costly than those employed in English practice. He died on the 7th of April, 1891, at the Melbourne Club, of Bright's disease and congestion of the lungs. He was elected a Member of the Institution on the 1st of December, 1868.

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ROBERT STODART WYLD, Jun., was born on the 12th of March, 1855, at Queensferry, close to where the great bridge now spans the estuary of the Forth. His father had been trained as a Writer to the Signet; but giving up the practice of the law, had settled at Queensferry, of which for many years he was the much respected Provost. Robert Wyld received his education at the Academy and University of Edinburgh. Having made choice of engineering as his profession, he served a pupilage of five years, from 1872 to 1877, under Messrs. J. and A. Leslie, whose extensive practice gave him an early experience in many kinds of engineering operations. During this time he attended the engineering classes of the late Professor Fleeming Jenkin, and that of geology and mineralogy under Professor A. Geikie. On the completion of his articles he was appointed by Messrs. Leslie as Resident Engineer at the waterworks then being constructed for supplying the town and district of New Cumnock. After some months he was transferred to Midlothian, and placed in charge of a section, 13 miles long, of the pipe-line conveying a new water-supply to the City of Edinburgh from the Moorfoot Hills, with all the reservoirs, bridges, and other works connected with it.

At the beginning of 1879 he was appointed Resident Engineer on the Scarborough Harbour Improvement Works, which consisted of the deepening of two harbours, widening and extending a pier, underbuilding old quay-walls, and other operations. This undertaking occupied him for two years, and in January, 1881, he returned to Scotland to superintend for Messrs. Leslie the construction of the Acreknowe Reservoir on the Hawick Waterworks. A few months later, namely, in October, 1881, he was selected to take charge of an important section of the Vyrnwy Waterworks, of the Liverpool Corporation. The portion of this great engineering undertaking more especially under his supervision consisted of 35 miles of the main aqueduct, including all the special works connected therewith. From the nature of the ground these were of a multifarious kind, and calculated to fully tax the resources of an engineer. They included reservoirs and tanks, with earthen embankments as well as with concrete and brickwork walls. filters, clear-water tank, valve-houses, cottages, new roads, bridges, culverts, crossings over rivers, canals, and railways, and three tunnels, having an aggregate length of about 4 miles. The cost of that portion of the great work with which he was connected exceeded £300,000. On the eve of its completion he

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was struck down by illness. A chill caught in March developed into rheumatic fever, which closed his career, on the 17th of April, 1891.

Mr. Wyld was remarkable for a singular gentleness and modesty, combined with a straightforward frankness, which gained him the respect and goodwill of all who came into close personal contact with him. His energy and enthusiasm in the discharge of his duties were unflagging. His professional skill and fertility of resource marked him out as one who, had he lived, would doubtless have gained a high place among the hydraulic-engineers of this country.

He made a short communication on "The Laying of Large Mains" to the Liverpool Engineering Society, which has been published.[1] He interested himself in the remarkable deposits of shell-bearing gravels cut through at high levels above the sea during the construction of the Liverpool Waterworks, and it was hoped that he might be induced to bring his observations before the Geological Society. But this and many bright anticipations for his future have been abruptly shattered by his premature death.

Mr. Wyld was elected an Associate Member of the Institution on the 4th of May, 1880, and was transferred to the class of Member on the 23rd of February, 1888; he became a Fellow of the Geological Society in 1890.

ARTHUR JOSEPH EDWIN ARCH was born at Brockley Hill, on the 4th of August, 1862. After receiving his education at Dulwich College and at King's College School, he was for several years engaged under a firm of London surveyors. Meanwhile he was studying at the City of London College under Mr. Henry Adams, and in April, 1885, passed the qualifying examination for the Professional Associateship of the Surveyors' Institution. In August, 1885, he joined the staff of the Rio Tinto Mines, under Mr. James Osborne. At Rio Tinto he was engaged in surveying various parts of the works and surrounding villages, gaining the good opinion of his superior officers. "He displayed the

[1] Transactions of the Liverpool Engineering Society, vol. x. p. 20.

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"greatest care in the different works, and the information obtained "was thoroughly reliable, and the plans very neatly executed. He "always showed great devotion to the work he had in hand." In August, 1887, he left Spain to proceed to Tientsin, China, as Assistant Engineer in the construction of the China Railway. He had shortly before passed the qualifying examination for the Fellowship of the Surveyors' Institution. In China he was employed on the construction of the line from Tientsin to Tongku. He also made surveys for the extension line to Siku, showing himself a capable and intelligent officer. In December, 1888, he left Tientsin to take up the appointment of Resident Superintendent of the Punjom and Sunghie Dua Samartan mines in the Malay Peninsula. His services were afterwards engaged to examine and report on various mining concessions in the Sultanate of Johore. In October, 1889, he was appointed to superintend the operations carried on by the Malay Peninsula Prospecting Company. While holding this appointment Mr. Arch prepared a valuable sketch map of Pahang concessions. In the course of this task he was compelled to undertake many adventurous journeys in unfrequented parts, on one occasion losing valuable memoranda and observations through the swamping of rafts in a Pahang river. In all his duties he gave every satisfaction to the Directors. At Christmas, 1890, he returned to England from the East, and early in 1891 left for Brazil, having received an appointment under the firm of Messrs. Brunlees and McKerrow, on the Brazilian Imperial Railway Extension. He met an untimely death by drowning in the Rio Paraguassu, near Bahia, on the 23rd of March, 1891.

Mr. Arch was characterised by a keen devotion to his work and an indomitable perseverance. He was possessed of a firm self-reliance, to which he owed in a large measure the success he had obtained. His early death cut short a career of much promise.

He was elected an Associate Member on the 10th of April, 1888.

JOHN BOURDEAUX was born in London on the 13th of August, 1834. At the age of fifteen he entered the service of the Electric Telegraph Company, with whom he stayed until 1859, when he received an appointment in the instrument department of the

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London offices of the Submarine Telegraph Company, and remained there until 1862, when he was transferred to Dover, and had charge of that and the Folkestone stations. Some few years after this, he was appointed Assistant Engineer under Mr. France, who retired from the Company's service in 1870, and Mr. Bourdeaux succeeded him as Engineer. Up to this time the cables, which were owned and worked by the Company, had been repaired by various tugs fitted with the necessary gear at Dover; but as time advanced, the work increased so much, that in 1871 it became necessary, in order that it might be more expeditiously effected, to have a steamer for the purpose, and eventually, under the direction of Mr. Bourdeaux, the paddle steamer "The Lady Carmichael" was built, and with it and other means the work was carried on much more satisfactorily than hitherto. He remained as Engineer to the Company until the transfer to the Post Office in 1889, and it was at this time that his health began to fail, owing, in the first place, no doubt, to anxiety during the valuation and purchase of the property, including the cables, which had been repaired so many times by him. He entered the service of the Post Office in the same capacity as he had previously held under the Company; but, owing to his shattered health, was never at any time really able to undertake his full duties. In January, 1890, he was confined to his house, and after a lingering illness, died on the 2nd of July of the same year. He was elected a Town Councillor of Dover, but at the expiration of his first term of office, finding he could not give sufficient time to his municipal duties, he did not stand again. When the Bell telephone was first introduced, Mr. Bourdeaux made many interesting experiments, at first with a single overhead line, which he had previously erected for the Town Council, from the police station to the water-works, and afterwards through some of the cables belonging to the Submarine Company between England and France.

He was elected an Associate Member on the 4th of March, 1879.

JOHN DIXON was born on the 2nd of January, 1835. He was the eldest son of the late Jeremiah Dixon, of Newcastle-on-Tyne, who came of a well-known Quaker family of coal-owners at Cockfield, in the county of Durham, some of whom were distinguished as engineers and scientists even in the last century. His uncle,

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the late John Dixon, was the first Chief Engineer of the Stockton and Darlington Railway, and was associated with George Stephenson in making the original surveys for that work. John Dixon, the subject of this notice, received his education at Dr. Bruce's school in Newcastle, and became, in January, 1851, an articled pupil of the late Robert Stephenson. Soon after the completion of his articles, he was appointed Engineer and Manager at the Bishopwearmouth Ironworks of the Consett Iron Company; but in 1864, after a brief adventure in iron manufacture at Bedlington, he removed to London, where he began a successful career as engineer and contractor, which was continued till his death. In this capacity he carried out many important works in various parts of the world, commencing with the landing-stages on the Thames Embankment, piers at Southport and at Douglas, Isle of Man, and the large iron piers and wharves at Huelva in Spain, for the Rio Tinto Company. A bridge over the Nile at Cairo was his next work, followed by extensive drainage and sanitary works at Rio Janeiro, and piers in Mexico and Parà on the Amazon.

In 1875, in connection with Mr. Richard Rapier, he got the concession for, and made, the first railway in China, from Shanghai to Woosung. It was very successful and popular among the natives for a time, but, owing to the prejudices of the ruling Mandarins, was bought by the Chinese Government and taken up in October, 1877;[1] not, however, before thousands of the people had had practical experience of its utility. Mr. Dixon's discovery of an unexpected supply of fresh water in the rock of Gibraltar was due to his geological knowledge, and brought him into high repute with the military authorities and the War Department, who purchased his concession. His next enterprises were in Portugal, where he constructed the Custom House piers at Lisbon, and a 60-mile line of railway, for which he was awarded by King Luis I. an Order of Merit. Bridges at Waterford in Ireland, and docks and harbour extensions at Port Talbot, in Wales, occupied him for some time, and almost his last important undertaking was the rebuilding of Hammersmith suspension bridge over the Thames, for the Metropolitan Board of Works.

But the work of all others which brought him most repute,

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[1] See Minutes of Proceedings Inst. C.E., vol. lix. pp. 274, and vol. ciii. p. 278. Also the History of the Shanghai and Woosung Railway, by G. J. Morrison, in the library of the Institution (in MS.).

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both for the public spirit and the ingenuity displayed in it, was the initiation and carrying out of the transport from Alexandria to London of the famous Cleopatra's Needle, now on the Thames Embankment, which bears his name on the bronze tablet of its pedestal. In this enterprise he was supported by the late Sir Erasmus Wilson, F.R.S., to the extent of £10,000, but, owing to the unfortunate salvage claims, he was a financial loser to almost the same amount—a fact which has never been sufficiently known and appreciated. In 1888 he was induced to visit the colonies in South Africa, in the hope of benefiting by the change, but, broken down in health, he never thoroughly rallied after his return, and died on the 28th of January, 1891, at the comparatively early age of fifty-six.

Mr. Dixon's personal qualifications were those which go to the making of a great contractor. Original in conception as regards the practical carrying out of works, and guarded by his engineering training against mistakes of a theoretical nature, he faced difficulties with a light heart and found them but a stimulant to greater efforts. He tendered for the construction of the Forth Bridge, and was quite prepared to undertake that work single-handed, but the directors did not deem it prudent to entrust it to any one man. His enthusiasm was contagious, and the hesitations and doubts of engineers and financiers were often swept away by his vigorous and cheery eloquence. He was an accomplished amateur artist, and his water-colour drawings, mostly sea-pieces, were frequently hung in various exhibitions in London. His loss will be deeply felt by a large circle of friends, who esteemed highly his great abilities, his indomitable enterprise and genial personal qualities, which will secure him a high position among Newcastle worthies. He was some years ago accorded by the University of Durham the honorary degree of M.A.

Mr. Dixon was a Lieutenant of the City of London. He was elected an Associate-Member on the 7th of December, 1869.

CHARLES HILTON HINGESTON was born in London on the 14th of May, 1858. He was a pupil of Mr. F. E. Duckham, and was engaged as his assistant on railway and other extension works at Millwall Docks, until August, 1882, when he was appointed Resident Engineer with sole charge of the submarine operations

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of the Stonehouse Pool Improvements for the London and South Western Railway. Upon the completion of those works in 1888, he was sent to Tasmania by the Long Reach Dredging and Tin Mining Syndicate, to take the management of their interests, and superintend the erection of their machinery. In May, 1890, he was appointed Colonial Engineer of the British settlement on the Gambia, with his headquarters at Bathurst. On the 22nd of the following September, he accompanied the Administrator to Albreda, and while there contracted malarial fever. The return to Bathurst was made as speedily as possible, but Mr. Hingeston died on the 1st of October. He was elected an Associate-Member of the Institution on the 4th of March, 1884.

JORGEN DANIEL LARSEN was born on the 26th of September, 1833, and was educated at the Polytechnic School at Copenhagen, with the object of following the profession of a Civil Engineer.

From 1856 to 1859, he was engaged on the Newcastle and Maitland Railway, New South Wales, as Contractor's Resident Engineer, and was employed from 1860 to 1862 in the Roads and Bridges Department in the Northern District of New South Wales, as a Government Assistant Engineer. He then spent some time in the United States for the purpose of studying the systems of Street Tramways. From 1866 to 1868, he was Engineer to the North of Europe Land and Mining Company, for whom he designed and carried out works. From 1869 to 1873, he was Resident Engineer to the London Tramways Company, and laid out and superintended the construction of all its lines. He also acted in the same capacity for the Pimlico, Peckham, and Greenwich Tramways Companies; and had charge of the construction of the tramways in Cardiff, Belfast, and Plymouth. He was Consulting Engineer for the tramways in Madrid; and from 1874 to 1879, was Engineer for those in Paris, both on the north and south sides of the river. In the middle of 1879, he proceeded to Johannesburg, where he was engaged for a short time in reporting on coal farms, &c. From 1881 to 1884 he was Resident Engineer on, and superintended the construction of, the Calcutta tramways for Mr. Hopkins. After visiting Melbourne to examine and report on the tramways in that city, he became engineer to the newly formed Johannesburg Tramway Company, and made all the necessary surveys and plans, prepared specifications for plant and rolling-stock, and super-

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intended the construction of some 3 or 4 miles of tramway, together with the necessary buildings, &c. This was completed in the face of much opposition and difficulty, and is now being worked successfully. The anxiety and strain had told visibly upon Mr. Larsen for some time, and in the month of March he had a paralytic seizure which terminated in his death on April the 20th.

Mr. Larsen was much respected, and the success of the Johannesburg tramways was in a great measure due to his experience and tact, as owing to the opposition they met with, and the nature of the route, the work was rendered one of real difficulty.

Mr. Larsen was by birth a Dane, but had become a naturalized British subject. He was elected an Associate Member of the Institution on the 1st of February, 1881.

JOSEPH MUSGRAVE was born on the 10th of March, 1812. He was apprenticed to Messrs. Rothwell, Hick, and Rothwell, of the Union Foundry, Bolton, and when Mr. Hick left that firm and built the present Soho Ironworks, Mr. Musgrave went with him, in a responsible situation. In 1838 was appointed Resident Engineer on the North Union Railway. He designed a skew bridge for the Lancaster and Preston Railway, consisting of a series of arches side by side, receding at the buttress or spring of the arch.

The Globe Ironworks, with which Mr. Musgrave's name is mainly associated, were founded early this century by his father, the late John Musgrave, who had up to that time been engaged in a responsible position at the Soho Ironworks, then belonging to Messrs. Benjamin Hick & Son. In its initial stage the Globe Foundry was of comparatively small dimensions; but thanks to the earnestness of purpose, and the ingenuity and ability displayed by the head of the concern, aided materially in subsequent years by his sons, Messrs. Joseph, Jonathan, John, and James Musgrave, the firm gradually extended its operations until at the present time the works cover a tract of ground, extending from Kay Street into Waterloo Street, and constitute one of the largest engineering and millwright establishments in the country. About a quarter of a century ago Messrs. Musgrave and Sons took up the cotton-spinning business, beginning with the erection of the No. 1 Atlas Mill, fronting Chorley Old Road, Halliwell, which was first put in operation about March, 1864; and the venture proving successful, fresh mills were added, the last extension to the spinning depart-

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ment being in 1887, when a sixth factory, for about one hundred thousand mule spindles, was constructed, which has been popularly called the "Jubilee Mill." Since then, the firm has also embarked in the manufacture of cotton cloth. Including the employees at the Globe Ironworks and those engaged in their spinning and weaving concerns, the firm have now in their service nearly three thousand workpeople of all ages. Mr. John Musgrave, sen., died on the 19th of December, 1864, at the age of eighty years; and since then Mr. Joseph Musgrave acted as head of the establishment.

In the question of local railway-improvements, Mr. Musgrave greatly interested himself at various periods. He was mainly instrumental in inducing the Lancashire and Yorkshire Railway Company to carry out the work of establishing and extending the Halliwell goods station many years ago, an addition which has proved of great benefit to the eastern and northern extremities of the borough. One of his latest efforts in the direction of railway development was his project for the extension of the London and North-Western line by carrying it over the central part of the town, from the present terminus in Great Moor Street to a suggested new site in Church Street, Little Bolton, a distance of about 900 yards. Mr. Musgrave had plans prepared showing the route of this contemplated addition, together with other particulars; and he brought the matter before the Bolton Chamber of Commerce in November, 1887. The project was heartily approved by the Chamber, and strong representations were made to the Railway Directors to induce them to carry out the work, but they declined to accede to the suggestion.

Mr. Musgrave was for twelve years a member of the Halliwell Local Board, during three of which he was Chairman. When the incorporation of Halliwell with the borough was first suggested, he was strongly against the proposal, but afterwards seeing that the township must benefit from the change, he supported the project heartily, and gave evidence in favour of it before the Committee of the House of Commons.

He was made Justice of the Peace in 1867, and in the exercise of this function showed much discrimination and thoughtfulness. In 1874 he was returned unopposed, as a councillor for the East Ward (in which the Globe Ironworks are situated); and in 1877, when that portion of the township of Halliwell which was within the Parliamentary borough became incorporated within the Municipal borough, Mr. Musgrave was chosen as one of the Aldermen for the new ward. The department in which he took

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most interest was the Water-works, for the development of which he, along with the other members of the Corporate Committee, had worked very hard. The last important Water-works undertaking which was inaugurated under the auspices of this Committee (of which he had been Chairman for several years up to his decease) was the new High Rid Reservoir, at Heaton, which is well advanced towards completion. It is calculated to hold about 100,000 gallons. As President of the Bolton and District Incorporated Chamber of Commerce, Mr. Musgrave — who held the office from the formation of the Chamber in 1887 up to his decease—achieved much valuable work on behalf of the trading community.

He was elected Mayor of Bolton in 1880. His name has been associated for many years with the Bolton Infirmary and Dispensary, to which he contributed liberally. He died on the 12th of January, 1891. Mr. Musgrave was elected an Associate Member on the 2nd of February, 1869.

ERNEST SPON was born on the 1st of August, 1849. He was regularly educated as a Civil Engineer for upwards of three years, from 1869 to 1872, in the office of the late Mr. Oliver Byrne, and subsequently spent eighteen months at the works of Mr. Thomas Don, millwright, of Reigate. He then entered into partnership with Mr. G. G. André, as Consulting Mechanical Engineer, being also largely employed in sinking wells. In 1879 he commenced practising on his own account; and in 1881 received the appointment of Engineer to the Explosives Company, for whom he designed and superintended the construction of new works at Pembrey, near Cardiff. The works of the Smokeless Powder Company, at Barwick, of which he was the manager, were designed by him. He was also Engineer to the Pembrey Old Harbour Board. His death, which occurred on the 28th of November, 1890, was totally unexpected. Two days previously he had started for Aberdare in order to carry out some important blasting experiments in a mine belonging to Mr. G. Brogden. At eleven o'clock on the date named the manager of the mine came to accompany him to the scene of the experiments, and it was then discovered that his bedroom door was

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locked on the inside. The police were called, and the door burst open, when Mr. Spon was found lying in bed with his right arm over his chest, apparently in a peaceful sleep; and Dr. Rhys, who was sent for, pronounced him dead. From the medical evidence at the inquest, it was evident that the cause of death was syncope, resulting from a sudden severe chill.

Mr. Spon was in many respects a remarkable man; he was deeply read, a good linguist, and a brilliant conversationalist. As an expert in explosives he occupied a high position. As an author he is best known by his popular and valuable book "Workshop Receipts." He also wrote the "Modern System of Well Sinking," partly edited "The Dictionary of Engineering," was editor of several colonial engineering papers, and contributed largely to the scientific journals. He was a great lover of natural history, and delighted in music and literature. For over twenty years he had been connected with the volunteers, and held the post of Lieutenant of the 1st City of London Artillery Volunteers. His father belonged to an old French family, and his uncles, Messrs. E. and F. N. Spon, are the well-known publishers. For many years the deceased had been a Freemason.

Mr. Spon was elected an Associate Member on the 2nd of May, 1882.

RICHARD MORELAND, the eldest son of John Moreland, a builder of chimney-shafts of 18, Old Street, St. Luke's, London, was born in Wilderness Row, Clerkenwell, on the 16th of February, 1805. After receiving an ordinary school education, he was apprenticed at the age of fourteen to Mr. Thomas Cooper, of 149, Old Street, London, for a term of seven years. In June, 1828, he started in business on his own account as a millwright in a neighbouring workshop in Teanby's Buildings, Old Street.

Mr. Moreland was of a very practical turn of mind; he was ingenious in designing work and accurate and rapid in the execution of it, and was looked upon by his fellow-workmen as a leading man. He took the opportunity of attending such evening classes as were then in existence for general improvement on those things which pertained to his business.

The millwrights of that period were a most intelligent and useful body of men. The greater part of their knowledge was

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derived from experience. They were equally handy at the anvil, the vice, the pattern makers' and carpenters' bench, and were masters in erecting work. When engaged away from the works they were then thrown completely on their own resources as regarded the carrying out of the work—the art of working from detail drawings not being then invented.

In March, 1831, he entered into partnership with Mr. Thomas Cooper, and the firm soon became celebrated for their mill gearing, which had lately superseded the old wooden lantern-wheels and pinions. They executed tread-wheel machinery for the various prisons, with grinding-apparatus, mustard- and drug-mills, &c., and had all the principal London and country breweries and distilleries on their books.

In 1832 Barclay's brewery was burnt down, from an explosion of malt dust in an elevator, and Messrs. Cooper and Moreland were called in to reinstate it. Mr. Moreland made the designs, working night and day, and executed the work in six months from the date of the fire.

In 1834 Mr. Cooper died, and Mr. Moreland purchased the business of his executors for £10,000, bringing into it his father, uncle, and brother-in-law, the two former as sleeping partners, and the latter as office-manager and book-keeper. The appliances of the workshop were crude and primitive up to about 1850. There were only half a dozen lathes of a very old type, and the turning was done exclusively with hand tools. For long work a bar of iron with a groove in it was fixed parallel to the axis of the lathe, and one edge of the tool, which was in the form of a T, rested in the groove while the other cut the metal. The boring was effected principally with boring bars, the feed being given with a leading screw.

The modern workshop-tools—introduced by Whitworth and other makers about the year 1840—were sparingly purchased, and it was not till 1856 that the necessity of adopting them was recognized. The traditions of the workshop were antagonistic to them. None of the wheels or couplings were bored to fit on the shafts or spindles. Key-ways were all cut with a chisel, and the shafts made with key-beds, so that under the circumstances the workmen were independent of machine tools.

In 1857 his son, Richard Moreland, became a member of the firm, the name of which was changed on the death of his brother-in-law to Richard Moreland & Son. Mr. Moreland retired from business altogether in 1886.

He took an active interest in charitable work. About 1852 the

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affairs of the Finsbury Dispensary, which had been established in the neighbourhood since 1780, were in a critical condition, and it was feared that it would have to be closed. This institution provided medical relief and attendance to the working classes in Clerkenwell and St. Luke's and the neighbourhood. Mr. Moreland at this juncture took the matter in hand, and, through his exertions and liberality, sufficient money was collected to put it in working condition. He held the office of honorary secretary for forty years, and a testimonial, in the shape of his portrait painted by Mr. John Pettie, R.A., was presented to him by the subscribers in the year 1886. He was a member of the Hospital Sunday Fund since its commencement.

He was appointed by Her Majesty's Commissioners for the Great Exhibition of 1851 one of the Local Commissioners for engineering and machinery. He was elected an Associate on March 8th, 1836. He died on the 18th March, 1891, of cystitis, after an illness of three months, in his eighty-seventh year.

Captain GEORGE CHARLES PARKER was born at Havant, Hampshire, on the 19th of February, 1836. His father was a captain in the Royal Marines, and his three brothers served in the Royal Navy. After receiving his education at the New Cross Royal Naval School, he was appointed on the 3rd of April, 1853, as a midshipman in the Indian Navy, in which he served until its abolition on the 30th of April, 1863, when he was retired as a lieutenant, and transferred to the Indian Marine, in which, in 1883, he was granted the title of captain.

While in the Indian Navy, Captain Parker saw much service in the two China wars of 1856–7, and 1860. He was in the Naval Brigade during the Indian Mutiny of 1857–58, and was mentioned in despatches. He took part in the expedition against the Wagheers in 1859, in which, at the assault and capture of Beyt, he was wounded, and his sword-hilt smashed by a bullet. The gallantry and coolness with which he commanded the "Zenobia's" field-piece party, and worked his gun under a heavy and destructive fire, were specially mentioned in despatches, which also spoke favourably of his services in the Naval Brigade at the siege and occupation of Dwarka, in the same expedition. He

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received the China war medal (with clasp for Pekin), and the Indian Mutiny medal.

Soon after his transfer to the Indian Marine in 1863, Captain Parker was appointed Port Officer and Superintendent of the Government timber depot at Carwar, when he surveyed the harbour, and received the thanks of the Hydrographer of the Admiralty for the chart which he prepared. He was also thanked by the Conservator of Forests for his able management of the timber depot.

He took fifteen months' sick leave to England in 1868–9, and was transferred in August, 1873, to the charge of the rising port of Karáchi as Master Attendant (afterwards called Port Officer). He entered upon this office at a time when the improvements of the harbour (on the plans of the late Mr. James Walker), which had been for several years in progress, had reached a stage at which his professional skill and zeal proved of great advantage to the Government and to the trade of the port, in fully utilizing the advantages so far gained for navigation, and in supporting the engineering proposals for the continuance and further development of the works. The growing importance of the place, which resulted from these undertakings, led to the establishment in 1880 of a Harbour Board, which in 1887 merged into the present Port Trust, and in the arrangements and working of both Captain Parker bore a prominent and most laborious part, not only as executive officer, but as member and vice-chairman of the respective boards. He also rendered valuable service, which was duly acknowledged by Government, in aiding the transport of troops and baggage animals, viâ Karáchi, in connection with the Afghan and Soudan wars, and in the fitting out and despatch of troops for the Malta Expedition in 1878, during one of the short periods in which he acted as Port Officer at Bombay. Latterly, also, he raised and formed the Karáchi Brigade of Naval Volunteers, in which H.R.H. the Duke of Connaught took much interest, during his inspection of the Karáchi defences in 1890.

He received the thanks of Government for his personal exertions and prompt measures in saving life and property in wrecks at or near Karáchi on four different occasions. All these labours, with heavy responsibility, in a trying climate, told on Captain Parker's health, and he reluctantly took sick-leave in October, 1890; but unhappily did not live to reach England, his death having occurred at sea on the 15th of November, 1890.

The Karáchi Port Trust Board placed on record their high appreciation of Captain Parker's services and advice, their deep

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regret for his loss, and sympathy with his wife and children, in a resolution dated 20th November, 1890, in which reference was also made to the feelings of all those who had been associated in work with him, or had served under him. Captain Parker was careful of the welfare of his subordinates, not merely as a matter of official duty, but as one who took a warm interest in the education of their children, and in their social gatherings and amusements.

In private life his sociable character will be long held in kind remembrance by a large circle of friends, who heartily sympathize with his family for the loss of one who may be truly characterized as a brave and skilful sailor, an able administrator, and a kindly and honourable man.

Captain Parker was elected an Associate on 2nd of December, 1884. He was a Fellow of the Royal Geographical and Royal Astronomical Societies, and a Member of the Royal Asiatic Society.

JOHN ALEXANDER RADCLIFFE was born at Salisbury on the 26th of February, 1823, being the fifth surviving son of the Rev. George Radcliffe, D.D., Prebendary of Sarum, who was well known in the south-west of England during the early part of this century as the headmaster of one of the largest of those private schools which have now almost entirely disappeared, but which then rivalled the leading public schools as centres of classical education. He inherited from his father an intensity of energy, which lasted throughout his life. Firmness of will, combined with great tact in dealing with men, a strong capacity for, and love of work, united to an almost instinctive perception of the main points at issue in any matter, were some of his characteristics; and these, added to great kindness of heart, integrity, and an honest devotion to the best interests of his clients, gained for him, to an unusual degree, their confidence and esteem.

Having received an excellent classical education in his father's school, Mr. Radcliffe, after being articled to a solicitor in Salisbury, proceeded to London for further training, and entered the office of Mr. Warry, a lawyer of some repute, in New Inn. His ability was soon recognized, and he had not been there long before he had the conduct given him of a *cause célèbre*, in which a well-

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known nobleman was interested, and which led to a journey over a great part of the Continent in search of evidence in days when railways were unknown. Shortly after his successful handling of this case, Mr. Radcliffe started business on his own account in Delahay Street, where, in conjunction with Mr. Edwards and other partners, he laid the foundation of a large and important practice. The era of railway making had then begun, and his firm soon got the charge of a large railway business, principally relating to lines in the west of England and Ireland. Here he was necessarily brought into close contact with the leading civil engineers of the time, and the connection thus formed continued uninterruptedly throughout the rest of his professional career. He was frequently associated with them as legal assessor in important arbitrations, and his advice was constantly sought with reference to the drafting of awards. He acted as solicitor for the Institution on many occasions, notably in the case when the Commissioners of Inland Revenue sought, unsuccessfully, to make the Institution liable for Corporation duty.

Mr. Radcliffe had frequent occasion to travel abroad under circumstances unusually favourable for acquiring information. Early in life he had been commissioned to visit America and report on its railway system. He had been to Egypt to advise upon large irrigation works; to Spain with reference to water-works. As director of the West Flanders Railway, he had represented the Board at more than one railway conference. He had some acquaintance with Italy, Switzerland, and Germany. Being thus a man of varied experience, brought into close intercourse with some of the most eminent persons of the day, with a retentive memory, and considerable conversational powers, he was a welcome guest wherever he went, while his warmth of heart and uprightness of character won him many firm friends, who will miss his wise advice and ready sympathy.

Mr. Radcliffe died on the 27th of January, 1891, leaving a widow and seven children surviving him. He was elected an Associate on the 7th of February, 1888.

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THOMAS WRIGHT was born in 1812, and was educated at Leeds. After serving an apprenticeship of seven years as a Mechanical Engineer under Mr. Goldthorpe, of Leeds, he became for three years foreman to Messrs. Hattersley and Son, of Bradford, after which he was, for a short time, in the establishment of Messrs. Joseph Whitworth and Co., of Manchester, and subsequently in that of Messrs. Sharp and Roberts, with whom he remained eighteen months. He then entered the locomotive department of the London and South Western Railway, where he stayed for about four years. He was next employed for five years in the office of Mr. Joseph Locke, being engaged during part of that time on the construction of the Barcelona and Mataro Railway, of which he afterwards became the Locomotive Engineer and Carriage Superintendent.

About 1851 Mr. Wright commenced business on his own account as a railway engineer. In 1856 he was appointed, on the recommendation of Sir Charles Hartley, agent in England of the European Commission of the Danube, for the selection and purchase of machinery and goods of all kinds required for the construction of the river-works from Galatz to the sea. The duties of this office he continued to discharge up to within a few months of his death, to the entire satisfaction of the Commission and its Resident Engineer.

It is interesting to note that as early as 1851 a scheme was brought forward by Mr. Wright for the establishment of a "Metropolitan Streets Tramway Company," the object of which was "to collect, condense, and systematize, as well as to cheapen, the transit of passengers, parcels, and goods through the streets of London and its environs." He proposed to "insert two lines of rails into and flush with the surface of the cart road," and stated, as a part of his scheme, that "the ground occupied by these rails after the trams shall have passed will be common to every other kind of vehicle as at present." The gauge was to be 4 feet 8½ inches, so that the wagons used on it could run on ordinary railways. The carriages were to be of the same width as an ordinary omnibus, but the wheels were to be placed underneath in lieu of at the sides, and he considered that three such vehicles carrying a hundred and twenty passengers could be propelled by one pair of horses. The fare for a single journey was to be 3*d.*, but "intermediate distances of a mile" would be charged at 1*d.*

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only, while for 6*d.* the passenger might change from one car to another till he arrived at his journey's end. A system of parcels delivery between the waiting-rooms provided for the passengers was also contemplated.

Another of Mr. Wright's proposals has been already realized, namely, that of the "Artillery Train." This idea was advocated by him in 1864, when he pointed out the great services which such a train might render in military operations, and showed how the difficulties arising from the concussion of firing and the recoil of the guns might be met.

For the last two years Mr. Wright had suffered from bad health, and the inclemency of the weather during the winter of 1890–91 brought on an illness which proved fatal. He died of bronchitis on the 20th of February, 1891, aged 79. In character he was remarkably straightforward and unpretending, and by his strict integrity and business-like qualities earned the confidence and esteem of all who knew him. Mr. Wright was elected an Associate of the Institution on the 5th of April, 1853.

*** The following deaths, in addition to some of those included in the foregoing notices, have been made known since the 10th of March, 1891:—

Members.

ANDERSON, HENRY JOHN CARD; *died* 25 March, 1891; *aged* 56.

BAZALGETTE, *Sir* JOSEPH WILLIAM, C.B., *Past-President; born* March, 1819; *died* 15 March, 1891.

FISHER, GEORGE; *died* 3 May, 1891; *aged* 81.

HARDCASTLE, WILLIAM JOHN, *Bey; died* 1 December, 1890; *aged* 61.

HAWKSHAW, *Sir* JOHN, F.R.S., *Past-President; born* 1811; *died* 2 June, 1891.

MARLEY, JOHN; *born* 11 November, 1823; *died* 4 April, 1891. (*Paralytic seizure.*)

PERKINS, LOFTUS; *died* 27 April, 1891; *aged* 56.

RENNIE, WILLIAM COUPAR; *born* 3 December, 1843; *died* 5 April, 1891.

RICHARDSON, ROBERT; *died* 21 March, 1891; *aged* 79.

RIDDELL, ROBERT; *died* 16 May, 1891.

SLAUGHTER, EDWARD; *died* 13 May, 1891; *aged* 75. (*Syncope following pneumonia.*)

WALKER, BENJAMIN; *died* 14 April, 1891; *aged* 70. (*Congestion of the lungs.*)

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Associate Members.

ATCHISON, ARTHUR TURNOUR, M.A.; *born* 5 November, 1857; *died* 19 March, 1891; *died* 21 April, 1891; *aged* 43.

MONTRESOR, CHARLES EDWARD CAGE;

Associate.

JACKSON, JOHN; *born* 3 February, 1834; *died* 14 February, 1891.

Information respecting the life and works of any of the above is solicited in aid of the preparation of Obituary Notices.—SEC. INST. C.E., 5 *June*, 1891.

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Sect. III.

ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

The Celluloid Slide-rule. By — Caville.

(Zeitschrift fuer Vermessungswesen, vol. xx., 1891, p. 119.)

The Author has had in constant use for two years a 10-inch slide-rule of the Gravét type made of celluloid by a German firm. With a view to ascertain the degree of accuracy attainable with this rule after two years' wear, he has made the following series of tests, in which the actual results were of course calculated and entered in the table after the slide-rule results had been noted :—

No.	Slide-rule Result.	Actual Result a.	Error δ.	$\frac{100\delta}{a}$	$\left[\frac{100\delta}{a}\right]$
				per cent.	
1	$2{\cdot}78 \times 8{\cdot}64 = 24{\cdot}02$	24·02	..	..	..
2	$9{\cdot}31 \times 1{\cdot}24 = 11{\cdot}53$	11·54	−0·01	0·09	0·0081
3	$2{\cdot}56 \times 8{\cdot}27 = 21{\cdot}14$	21·17	−0·03	0·14	0·0196
4	$1{\cdot}23 \times 2{\cdot}43 = 2{\cdot}99$	2·99	..	..	..
5	$9{\cdot}01 \times 6{\cdot}75 = 60{\cdot}75$	60·72	+0·03	0·05	0·0025
6	$8{\cdot}04 \times 7{\cdot}94 = 63{\cdot}8$	63·84	−0·04	0·06	0·0036
7	$9{\cdot}95 \times 6{\cdot}41 = 63{\cdot}8$	64·05	−0·25	0·39	0·1521
8	$1{\cdot}52 \times 20{\cdot}5 = 31{\cdot}2$	31·16	+0·04	0·13	0·0169
9	$7{\cdot}18 \times 16{\cdot}4 = 117{\cdot}8$	117·75	+0·05	0·04	0·0016
10	$3{\cdot}65 \times 11{\cdot}3 = 41{\cdot}3$	41·25	+0·05	0·12	0·0144

Thus, for this series, the error $m = +\sqrt{\frac{0{\cdot}2188}{10}} = 0{\cdot}15$ per cent., or approximately 1 in 650.

In the following series the calculations consist of combined multiplications and divisions, involution and evolution :—

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No.	Slide-rule Result.	a.	δ.	$\frac{100\delta}{a}$	$\left[\frac{100\delta}{a}\right]^2$
				per cent.	
1	$\frac{6{\cdot}5 \times 3{\cdot}74}{2} = 12{\cdot}15$	12·16	− 0·01	0·082	0·0067
2	$8520 \div 6{\cdot}35 = 1342{\cdot}0$	1341·73	+ 0·27	0·020	0·0004
3	$725 \div 12{\cdot}35 = 58{\cdot}69$	58·70	− 0·01	0·017	0·0003
4	$735^2 = 54{\cdot}01$	54·02	− 0·01	0·019	0·0004
5	$735^3 = 397{\cdot}0$	397·05	− 0·05	0·013	0·0002
6	$\sqrt{1654} = 40{\cdot}65$	40·67	− 0·02	0·049	0·0024
7	$\sqrt{754} = 27{\cdot}49$	27·46	+ 0·03	0·109	0·0119
8	$\sqrt[3]{684} = 8{\cdot}82$	8·81	+ 0·01	0·113	0·0128
9	$\sqrt[3]{216} = 6{\cdot}00$	6·00	..	..	..
10	$\frac{4{\cdot}35 \times 7{\cdot}89 \times 18{\cdot}5}{17{\cdot}4 \times 12{\cdot}5} = 2{\cdot}92$	2·92	..	..	..

Thus, for this series, the error $m = +\sqrt{\frac{0{\cdot}0351}{10}} = 0{\cdot}06$ per cent., or approximately 1 in 1,700.

Three similar series gave 0·05, 0·07, and 0·06 per cent. respectively. The average error may therefore be taken at 1 in 1,500. The greater degree of accuracy obtained in the second series may be due to the fact that the intermediate result may be fixed with greater accuracy with the cursor than it can be read with the eye. Possibly, too, by combining several operations errors are neutralized.

B. H. B.

Periodical Movements of the Ground as Indicated by Spirit-Levels.[1] By P. Plantamour.

(Archives des Sciences Physiques et Naturelles, Geneva, vol. xxiv., 1890, p. 441.)

The Author recounts his twelfth (and last) year's level-observations, in which he restored to its original position and direction the spirit-level, which previous to October 1886 had been oriented south-north, and which for the last three years had been placed nearer the centre of the house, and oriented east-west, in order to compare its readings with the other spirit-level similarly oriented, but placed near the outer wall of the house. He found its indications similar in all respects to those of the first eight years; *i.e.*, that the oscillatory ground-movements have less

[1] Minutes of Proceedings Inst. C.E., vol. liv. p. 286; vol. lx. p. 342; vol. lxiv. p. 343; vol. lxviii. p. 321; vol. lxii. p. 324; vol. lxxv. p. 326; vol. lxxix. p. 375.

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amplitude in this direction than in that of east-west, and that the south end in addition experiences other movements than those produced by the temperature and acting in an *opposite* direction, the cause of which is still an enigma.

The inclination of the east end has diminished 1·44 second of arc, and the mean inclination for the year 2·14 seconds, as compared with the preceding year. The east end reached its lowest point (−124·85 seconds) on 6th March, 1890, the minimum of the south end (−2·24 seconds) occurring also on the same day, while the lowest reading of the mean temperature occurred on 2nd March, or four days earlier. The highest mean temperature for the twenty-four hours was taken on 26th June, whilst the maximum rise of the east end (−99·18 seconds) occurred on 18th August, fifty-three days after, and that of the south end (+ 3·98 seconds) on 29th May, twenty-eight days in advance of, the maximum temperature. These anomalies have existed in the previous years, and are not easy to explain; but, generally speaking, the ground-movements coincide with those of the temperature.

After twelve years' patient investigation the Author insists that the regularity and accuracy of the indications of the ground-movements by the spirit-levels cannot be questioned, although definite conclusions as to the causes which produce these movements cannot yet be deduced. The anomalies in the level-readings prove that one or more factors, besides the temperature, must influence these ground-movements. He concludes by expressing the hope that these level observations will be continued at Geneva and elsewhere, until definite conclusions can be deduced therefrom.

E. H. C.

Shaft-Surveying at the Przibram Mines.

(Oesterreichische Zeitschrift fuer Berg- und Huettenwesen, 1890, p. 301.)

The government mine-surveying department publishes a full account, illustrated by means of two drawings, of the survey of the Kaiser Franz-Josef shaft at Przibram—probably the most complicated and difficult mine-survey ever executed. In 1875 the Adalbert shaft attained a perpendicular depth of 1,000 metres (3,280 feet). The same horizon, the thirtieth level, was reached by the Maria shaft in 1879, the depth from the surface being 1,010 metres (3,313 feet). In order to facilitate the haulage from this enormous depth, it was decided in 1879 to sink a third shaft to this level. The shaft selected was the Franz-Josef, which at that time had reached the seventeenth level, a depth of 421 metres (1,380 feet) from the surface. In order to accelerate the construction of the shaft, it was arranged to work at several levels by sinking and rising. The work was conducted at the following levels:—

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						Feet.
Between the	17th	and the	23rd,	with a rock-thickness of	. . .	755
„	23rd	„	25th,	„ „	. . .	249
„	25th	„	28th,	„ „	. . .	500
„	28th	„	30th,	„ „	. . .	360

The total thickness of rock to be driven through thus amounted to 1,864 feet. Before the shaft could be begun, it was necessary to drive cross-cuts of various lengths at the twenty-third, twenty-fifth, twenty-eighth, and thirtieth levels. Besides these, a cross-cut had also to be made at the twenty-sixth level. The success of the project was obviously dependent on the accuracy of the determination of the shaft axis at the different levels, and the survey consequently had to be extended over a large area of the Maria-Adalbert mine. A survey had first to be made at the twelfth level, where the three shafts (Maria, Adalbert, and Franz Josef) were already connected, in order to accurately determine the triangle formed by them. The well-known problem of connecting the surveys at different levels by means of two perpendicular shafts was then repeated five times. The following are the results of the determination of the shaft triangle at the twelfth level, the instrument used being a mining theodolite with two verniers reading to one minute:—

Sides of the Triangle.		Angles opposite.			
	Metres.		°	′	″
a. Maria-Adalbert . .	561,091	*α*. At Franz . . .	90	34	58
b. Maria-Franz. . .	340,091	*β*. At Adalbert . .	37	18	28
c. Adalbert-Franz . .	442,828	*γ*. At Maria . . .	52	6	34

The total length of levels traversed amounted to 1,120 metres (3,673 feet), the number of stations being forty-four. When the holing was effected (January, 1883), the survey at the twenty-third level gave the following results:—

Sides.		Angles.			
	Metres.		°	′	″
a_1.	561,045	α_1.	90	35	40
b_1.	340,054	β_1.	37	18	21
c_1.	442,740	γ_1.	52	5	59

The length traversed amounted to 1,960 metres (6,430 feet) with seventy stations. Corrections being made for instrumental and other errors, the following mean results were taken:—

Sides.		Angles.			
	Metres.		°	′	″
a_{11}.	561,055	α_{11}.	90	35	17
b_{11}.	340,064	β_{11}.	37	18	25
c_{11}.	442,773	γ_{11}.	52	6	18

and with these data, the shaft was continued by sinking from the twenty-third and rising from the twenty-fifth level. The shaft

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was made of full dimensions, $19\frac{3}{4}$ by $6\frac{1}{2}$ feet, and on holing the sides exactly coincided. A check survey at the twenty-fifth level gave the following results:—

	Metres.		°	′	″
a_2	560,990	α_2	90	36	41
b_2	339,793	β_2	37	16	37
c_2	442,762	γ_2	52	6	42

In order to obtain these results, a traverse of 2,200 metres (7,217 feet) with ninety-two stations was necessary. The variation of these results from those obtained at other levels is due to the difficulty of rendering so long a plumb-line perfectly stationary. Lastly, for fixing the shaft-axis at the twenty-eighth and thirtieth levels, the arithmetical mean of the three previous surveys, at the twelfth, twenty-third and twenty-fifth levels, was taken, the sides and angles being—

	Metres.		°	′	″
a_m	561,042	α_m	90	35	45
b_m	339,979	β_m	37	17	49
c_m	442,777	γ_m	52	6	26

The holing was effected in December, 1889, after the axis had been determined at the twenty-eighth level by a traverse of 1,110 metres (3,640 feet) with forty-four stations, and at the thirtieth level by a traverse of 1,520 metres (4,987 feet) with fifty-two stations. The coincidence was so exact that not the slightest change in the masonry or timbering was necessary.

In order to give an idea of the magnitude of this survey, it may be noted that all the operations were repeated, and that for the construction of the cross-cut at the twenty-sixth level, a further traverse of 1,020 metres (3,345 feet) with forty stations was required. The total distance traversed amounted to 11 miles, with 684 stations.

B. H. B.

Tunnel-Surveying on the Croton Aqueduct. By F. W. Watkins.

(Transactions of the American Society of Civil Engineers, vol. xxiii. 1890, p. 17.)

With the aid of eight plates, the Author describes the methods of surveying for shaft- and tunnel-work adopted in Division No. 6 of the Croton aqueduct tunnel, which extends from a point near the northern boundary of New York city to the Harlem river, a distance of 24,140 feet. The tunnel was driven from six shafts; the distance between them, and the depth from the surface being as follows:—

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Shaft.	From Surface to Invert.	From Top of Curbing to Invert.	Distance between Shafts.
No.	Feet.	Feet.	Feet.
19	56·83	57·00	..
20	128·87	138·82	3,116
21	115·21	135·51	5,426
22	94·11	104·65	6,925
23	78·21	86·17	3,940
24	189·96	205·07	4,280

In the alignment there were three changes of direction; whilst the grades changed very considerably. The shafts were placed longitudinally with the axis of the tunnel, and on one side of the centre line, so that the wires should not interfere with the cages in the shaft. It was found that the centre-line wires were very difficult to distinguish, as the cross-hair of the telescope and the two plummet-lines appeared so nearly alike. The Author was therefore induced to devise an illuminated slit apparatus to replace the wires at the bottom of the tunnel. This instrument consists of two vertical strips of brass, 3 inches in height, attached to separate horizontal bars, moving in guides, and provided with a tangent-screw motion, by which one or both could be moved right or left, and the vertical aperture between them made as small as desired. One of these instruments was screwed to a plank-bracket close behind each plummet-wire, and so placed that the farther one could be seen through the theodolite in line just above the other. When these slits were adjusted so as to be directly behind the plummet-wires, the latter were removed, and lights placed behind the slits. In this way two fixed and illuminated points were substituted for the wires.

For test-alignment work, a point was selected in each heading some 150 feet from the shaft. Holes were then bored in the roof to a depth of 8 inches, and wooden plugs inserted. Into these flat spikes of iron, 9 inches long, were driven. To these spikes a horizontal brass plate was bolted, with a zero mark cut on its lower edge. A movable vernier-bar was then hung under the brass plate, so that the distances east or west of the zero mark of a new test-line could be read off. The Author records a number of alignment-tests made in this way, the results showing that the accuracy of the surveys was very remarkable. In order to reach the plugs in the roof for hanging lines in a circular tunnel, ordinary ladders were not available, and consequently tripod ladders were devised which would stand alone.

For taking cross-sections for measuring the areas and quantities of excavation, the Author devised an instrument consisting of a circular disk or protractor, 3 feet in diameter, attached to a vertical iron rod capable of moving up and down in a socket, regulated by a thumb-screw. It was supported by a tripod with extensible legs, made of wrought-iron gas-pipe. The disk was set in the plane of the axis, and its centre made to coincide with that of the

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circular tunnel. Cross-sections were then taken, the measurements showing at once where any trimming was necessary. This instrument worked well, but was rather heavy. A lighter form was devised by Mr. A. Craven, who used a wooden tripod, a shifting top, a ball-and-socket joint, and levelling screws. A vertical brass tube slides through the socket, and carries at its top a wooden graduated disk, 18 inches in diameter. An arm revolving on a central socket traverses the face of the disk, and a wooden measuring rod, 14 feet in length, is placed on this rest in front of the disk, and slid out to touch the surface of the tunnel, the end of the rest at the same time indicating the angle from the vertical. In order to ensure the cross-section being taken at right angles to the axis of the tunnel, the disk is provided with a small sighting-tube, perpendicular to its face. The areas of the cross-sections are either calculated from the field-notes, or measured with the polar planimeter. In the Croton aqueduct-tunnel sections were taken every 10 feet over 30 miles of tunnel.

B. H. B

The Construction of Roadways across Peat-Bogs.

By A. Schacht.

(Zeitschrift des Architekten- und Ingenieur-Vereins zu Hannover, 1890, p. 749.)

As the instances of high-roads crossing peat-bogs or mosses are not very numerous, the records of the methods adopted in their construction are few. In most cases the surface of the underlying solid ground is above the level of the water-ways of the district, and this is illustrated by a diagram, showing a section of the natural formation along the course of the Hunte-Ems canal, between the River Hunte, in the Weser basin, and the River Vehne, in the Ems basin. The length shown on the section is 6 miles long; the ordinary level of the water in the Hunte is about 15·75 feet above datum, and the level of the immediately adjacent land is about 23·30 feet above datum. The ground is there of a solid nature, and the section shows the surfaces of this and of the overlying peat, the latter being shown by two contours, representing its surface in 1846 and again, after being drained, in 1887. The solid ground falls gradually, until about 1½ mile from the Hunte, to a level of 19·70 above datum, and thence rises to the summit at 4 miles, where it is 46·60 above datum, and falls thence to the Vehne.

The moss commences at about two-thirds of a mile from the Hunte, and continues to and across the Vehne, its greatest thickness being at a point about 2 miles from the Hunte, and where it was originally 29 feet 6 inches deep.

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Its thickness at the summit was 8 feet 3 inches (2·5 metres), and at the Vehne 6 feet 6 inches (2 metres); the latter stream-bed, being entirely in the peat, is in the summer usually dry.

The above instance having been quoted as an example of the mosses of Northern Germany, the Author deals with the question of the construction of roadways laid upon the surface of the moss.

An undrained moss consists of about 90 per cent. of water, and 10 per cent. of vegetable matter, and consequently while in that condition quite incapable of sustaining a roadway. By gradual drainage, however, the fluid mass is condensed into a more or less dense peat, but it is of great importance that this should not be attempted to be effected at too rapid a rate, as there is a liability of the escaping water carrying off with it the particles of vegetable matter, causing the sides of the ditches to collapse, and the production of fissures on the surface of the moss which, becoming filled with water, and ice in winter, extend more and more.

The drainage of the strip of moss along the site of the intended roadway should be effected by side-drains, carried gradually down, and into the solid underlying ground; and if this can be done, it is probable that the moss by conversion into peat will be reduced by about one-third of its total thickness. It is recommended that in making the drains, the sides, instead of being sloped, should be cut in a series of steps or benches, each of about 3 feet 3 inches deep, and 3 feet 3 inches broad, down to the requisite level, so as to expose as large a surface as possible to the influence of wind and sun, and thereby produce a comparatively hard skin of dry peat, and consequently lessen the destructive action of frost.

Supposing it be required to make a roadway of 10 metres (32 feet 9 inches) broad across a moss of 6 metres (20 feet) in thickness, it is recommended that, to begin with, a surface of 1 foot 8 inches to 2 feet 6 inches broad and deep should be cut parallel with the centre-line of the roadway, and at a distance of from 36 to 46 feet on each side of the axis, depending upon the width of the cess (viz., from 6 feet 6 inches to 16 feet 6 inches) which it is intended to leave between the edge of the roadway and the side drain. At right-angles to these and across the roadway, similar drains should be cut about 32 feet 9 inches apart, extending laterally across and beyond the side-drains, and from 130 to 160 feet long. The excavation from these drains should not, however, be deposited near their edges, or slips will probably occur, but laid on the roadway site, as it will have to be used for refilling the cross-drains later on. This work having been executed in the first summer, during the next season all drains can be deepened to the extent of a further 1 foot 8 inches or 3 feet 3 inches, and the sides, in the case of the longitudinal drains, widened 1 foot 8 inches ($\frac{1}{2}$ metre) or more. In the third year all the drains can be further deepened in like manner, care however being taken to keep the transverse drains crossing the road site as narrow as possible.

A matter of the greatest importance is to prevent the formation of fissures longitudinally on the site of the roadway, transverse

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fissures being of but little importance. The foregoing forms only the preliminary process of drainage, and it must depend upon the nature of the moss as to whether four, five or more years will suffice for bringing it into a condition sufficiently solid to allow of the forming of the roadway, composed of sand, etc., topped with metalling.

The Author refers to the remains of Roman causeways which are discovered occasionally at a depth of from 3 to 6 feet below the surface of some of the mosses in North-West Germany. They are formed of longitudinals of rough-hewn timber, overlaid by transverse timbers of lighter scantling.

D. G.

On Componential Trusses. By H. B. Seaman.

(Transactions of the American Society of Civil Engineers, Dec., 1890, p. 277.)

This paper describes a pair of compound trusses constructed to carry the stringers of a travelling-crane which was to convey heavy blocks of marble across the tracks of the Baltimore and Ohio Railroad.

The span to be bridged was 100 feet, and the various elevations of the railroad and of the buildings to be served by the traveller were such, that, combined with the existing traveller, it was not possible to employ a girder more than 2 feet 5½ inches in depth. The shape of the traveller, extending 12 inches beyond the rail, was prohibitive of the use of a deep truss outside the stringer because of the lateral moment produced. The design finally adopted was a pair of compound trusses of triangular cross-section, consisting of three chords, one vertical web-system, one inclined web-system, and a horizontal web-system; the vertical web-system being outside.

The final span was reduced to 87 feet 7 inches. The truss-depth from out to out of the chords vertically was 8 feet, giving a ratio of $\frac{\text{span}}{\text{depth}}$ of close upon 11. The horizontal componential truss was 4 feet between centres of chords, and the inner lower chord, which was common to the vertical and horizontal web-systems, was also the box-girder, which carried the rails of the traveller, and, including a 6-inch wooden stringer, only measured 2 feet 4½ inches from base of rail to clearance beneath.

Each 61-foot box-girder of 2 feet depth, as employed when the tracks to be crossed had not been widened, weighed 28,000 pounds, or 460 pounds per foot, so heavy a weight being due to a desire to reduce deflection.

The new componential trusses of 87 feet 7 inches weigh 34,000 pounds each, or 390 pounds per foot only.

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The weights taken for calculation were a live load of 30,000 pounds on two wheels 6 feet apart; a dead load of 400 pounds per foot.

Panel load,	outer chord	750 lbs.
„	stringer chord	1,750 „
„	top chord	1,050 „

There are thus two separate end support reactions; that under the outer or vertical web-system passing directly to the vertical system, whilst the reaction beneath the inner lower chord or stringer passes partially by the inclined web-system and partially by the horizontal system, which takes of course the strains arising from the horizontal component of the stress in the end oblique strut.

The stresses in all members are tabulated, and the Paper is accompanied by six lithographed plates.

The trusses have continued to give satisfaction since their erection, though many adverse opinions were volunteered. The first load to which they were subjected was one of 14 tons (28,000 pounds), carried close to one of the trusses, and which, with the weight of the traveller itself, was probably fully equal to that for which the trusses were designed.

W. H. B.

The Malleco Viaduct, Chili. By H. Mamy.

(Le Génie Civil, vol. xviii., 1891, p. 277, 1 Plate, 9 Cuts.)

The Author introduces his description by stating that the total length of railways in Chili in the year 1889 was 1,740 miles, of which 750 miles belonged to the Government and 990 miles to private companies.

Since that date the Government has encouraged emigration to Araucania, and for this purpose is now constructing a line of railway 310 miles long, which passes through the south of Chili, along the valley which separates the Cordilleras of the coast from the Andes proper. This line will be merely a continuation of that which serves the valley running from Santiago to the Bio-Bio river.

The viaduct of Malleco is at the point where the new line begins, and is one of the largest works of its kind in Chili.

The River Malleco itself is only about 20 yards wide, but it runs in a valley with very steep sides, so that a viaduct was necessary in order to cross it. Mr. Aurelio Lastarria, a Chilian engineer, prepared the original plans, and, after tenders had been obtained from Europe, the work was placed in the hands of the Creusot firm in France, who have carried out the whole of the construction.

The viaduct carries a single-track of railway of 5 feet 6 inches

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gauge, and its total length is 1,140 feet. The principal girders are supported by masonry abutments at each end, and by four columns of open ironwork, so that the viaduct consists of five equal spans of 228 feet each. The two main girders are placed at a distance of 14·7 feet between centres, and are 23 feet between the covering plates.

The whole of the struts and ties are of a U section. The Author then enters into details as to the dimensions of the different members of the girders, and states that with the double system of staying, both in a horizontal and vertical plane, that the viaduct is well able to withstand deformation from either wind-pressure or a rolling-load. There are two foot-ways between the ends of the sleepers and the sides of the girders, and a hand-rail 5 feet high is carried the whole length. The open ironwork columns which support the viaduct are of different heights; the two nearest to the abutments are 143 feet high, measured from the top of the stone foundation to the summit. One of the other two is 222 feet high, and the second is 248 feet high. These four columns have to support the entire weight of the girders, and also the lateral pressure of the wind. The bases have been therefore firmly anchored into the masonry in a most complete manner. All the capitals of these columns are of the same size, 14·8 feet across the viaduct, and 9·8 feet in a longitudinal direction.

The columns are constructed of four principal pillars which support all the weight, each pillar being composed of eight bars of U section. The diameter of a circle inscribed within the bars is 20 inches, while the circle described about the projections of the bars is 27·25 inches. The central pillar has been made of similar section to the other four pillars, although it does not carry any of the load. Particulars are given of the dimensions of the tie-rods and struts of the pillars. The columns are anchored down to the masonry foundations, and are provided with plates in such a way that the mass of masonry held by the tie-rods is 24·5 feet deep. The tie-rods are made of wrought-iron, and are 6·6 inches diameter for the two high columns, and 5·45 inches diameter for the shorter columns; they are screwed at the ends, and the nuts are tightened up while the rods are heated, in order to prevent loosening caused by vibration. The main girders are fixed to the two central columns, and the expansion of the centre girders caused by a rise of temperature is too small to injuriously affect the columns at such a height above their base, but the weight of the viaduct is carried upon rollers upon the other two columns, and upon the end abutments.

The material used throughout has been mild steel, and the breaking stress required in the test-pieces was 28·5 tons per square inch with an extension of 25 per cent. on a length of 3·94 inches. The test-pieces used had a width of 1·18 inch, and a thickness corresponding to the particular plate tested, and the average results given were a maximum breaking load of 30 tons per square inch with an extension of 28 per cent. upon 3·94 inches.

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Tables are given of the maximum bending moments of the five spans with various loads, and also of the shearing loads.

The maximum load is obtained with a locomotive of 46 tons weight carried upon four axles, at a distance of 4·6 feet between centres.

In the calculations for stability of the structure, a maximum wind-pressure of 55 lbs. per square foot has been allowed for when the bridge is unloaded, and of 35 lbs. per square foot when a load is upon it. The members have been so calculated that under the combined action of both wind and load, the stress does not exceed 6·35 tons per square inch.

The masonry work for the viaduct which had been at first placed in the hands of the contractors was begun in 1886, but it proceeded very slowly for the first two years, and it was only in 1888 when the Chilian Government took the work in hand that progress was made. Mr. Aurelio Lastarria was the chief engineer, and after his death Mr. Edward Vigneaux, also a Chilian engineer, took charge of the work.

The tests of the completed viaduct began upon October 11, 1890, and were made conformably to the French law of 1877.

E. R. D.

Hydraulic Apparatus for a Swing-Bridge at Ghent.

By E. Braun.

(Le Génie Civil, vol. xviii., 1890, p. 247. 1 Plate.)

A swing-bridge has been built at Ghent for the entrance of the dock-basin. The platform is about 130 feet long, 72 feet being for the approach. The width is 26 feet and the weight 150 tons. A type of hydraulic apparatus is used to work the bridge, which has now been in use four years and given excellent results. It consists of three parts:—

1. The motor itself. 2. The apparatus for transmitting the power from the motor to the platform of the bridge. 3. The controlling gear.

The motor is a Dulait turbine driven by the town water-supply, which is at a pressure of 51 lbs. The axis of the turbine is vertical, and turns only in one direction.

2. The axis carries a friction-cone made of leather disks compressed and cemented together. This cone is placed in the centre of a vee-shaped groove in the rim of a pulley, which can slide sideways upon a key let into the shaft, so that according as one or other side of the groove is driven by the rotary cone, so the bridge is closed or opened. The work is thus done by friction alone, which allows the bridge to be suddenly locked while moving quickly without risk of breaking any gearing. The turbine rotates at 200 to 250 revolutions per minute, while the bridge

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makes a quarter turn in seventy-five seconds, so that gearing is employed to obtain the necessary speed. The gear-wheels are keyed upon the same shaft as the pulley with the vee-groove, and drive another shaft which carries a wheel gearing into a circular rack fixed under the platform of the bridge.

3. The controlling-gear consists of two parts; that which governs the admission of the water, and that which controls the direction of movement of the bridge. The admission of water to the turbine is regulated by a sluice-valve which is controlled by a vertical spindle, which carries a grooved pulley, round which a steel-rope is coiled one complete turn; one end of this rope carries counterweights and the other is attached to a piston working in a small cylinder. The position of the piston is controlled by the admission of water under pressure. The gear for controlling the position of the friction-pulley is also worked by a water-cylinder. The water-pipe to the turbine is 5·85 inches diameter, while the pipes to the small cylinders are only 0·78 inch diameter. The controlling-valves and pressure-gauges are all in the cabin of the bridge-keeper. The apparatus can also be worked by hand-power if necessary, and in that case two men are required and the movement of the bridge is slower. The water used for the turbine is 77 gallons for each rotation of the bridge in seventy-five seconds. The price of water at Ghent is 2·3*d.* per 1,000 gallons, so that each movement of opening and closing the bridge costs 0·35*d.* The bridge opens about thirty times a day; the expense for water is therefore about 10*d.* The first cost of the plant was £160, and the cost for maintenance has so far been almost nothing. The water passes through a grating to avoid any chance of solids entering the turbine. The locking-apparatus consists merely of four cams fixed on the ends of the bridge, which are enabled to mount inclined planes owing to the speed of movement; at the end of its course the bridge strikes a spring-stop and is held by a hook. The hook is lifted on commencing a movement, and the springs assist the turbine to start the bridge.

E. R. D.

The Inland Navigation of Spain.

(Anales de la Construccion y de la Industria, Madrid, 1890, pp. 321, 337, 353.)

River-navigation in Spain has been much neglected; it is generally limited to the tidal waters near the coast, and there are only two navigable inland canals, the Canal of Castile and the Imperial Canal of Arragon. The first of these traverses the table-land of Old Castile, 80 miles running N.E. from Valladolid to Alar del Rey at the foot of the Cantabrian mountains, and a branch of about 50 miles running due E. from Dueñas to Rio Seco. It is

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expensively constructed, 50½ feet wide at the surface, 40 feet at the water-level, and 19 feet 6 inches at the bottom; the depth of water is 6 feet 6 inches. The larger half of the works were executed towards the end of the eighteenth century at the cost of the State, but they remained unfinished and neglected until 1831, when they were taken over by a private company which completed them in 1849, under a Royal Concession, with seventy years to run from the latter date.

The traffic consists chiefly of flour, corn, and coal, conveyed in barges of 35 tons burthen drawn by horses; and there are forty-nine locks, at which the average fall of water is 10 feet 10 inches, which also supply water-power to thirty flour-mills and fifteen other factories paying tribute to the Canal Company. Since the opening of the railways from Valladolid to Santander, and from Palencia to Leon, the average annual traffic has decreased from 63,606 tons, during the quinquennial period 1875–1879, to 40,161 tons in 1880–1884, and to 22,324 tons in 1885–1889; and the annual gross receipts have fallen from £5,766 to £4,377 and to £3,037 during the corresponding periods, less than half of which were derived from the navigation-tolls.

The Imperial Canal of Arragon derives its water from the Ebro, and runs parallel to that river from Tudela to Saragossa, a distance of 53 miles, with an extension of about 3 miles below the latter city, and two short branches from Saragossa, together 7½ miles in length, named the Miraflores and the Burgo. Originally built by the State in the sixteenth century as an irrigation canal, without locks, and with an average fall of 1 in 200, it was enlarged between 1770 and 1790, and rendered navigable for vessels of 100 tons drawing 10 feet of water, but the strong current makes the ascent difficult from Saragossa to Tudela. Moreover, a railway has been built running parallel to it which carries off the traffic from the canal, and its waters are now chiefly used for the irrigation of about 70,000 acres of land, and for supplying water-power to sixty-eight mills. For these services the State is satisfied with very low charges, and, although the canal has cost the State altogether £800,000, the net revenue, in 1888 from all sources, did not exceed £1,482.

With the view of rendering the Ebro navigable from Saragossa to the Mediterranean, extensive works of canalization were commenced about forty years ago. It was soon found that this was a very formidable undertaking, and the portion between Saragossa and Escatron had to be abandoned; but after an expenditure of nearly £700,000 the canalization was considered to have been successfully completed from Escatron to the sea. Meanwhile, however, the railways from Saragossa to Barcelona, and from Lerida to Tarragona had been built, and when in 1858, the navigation was formally inaugurated it was found that neither goods nor passengers presented themselves for conveyance. The steamers which had been provided had to be sold, and only a few small coasting vessels, and one small daily steamer ply now at the

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mouth of the river below Tortosa. In 1889 this traffic was limited to 3,448 tons.

Seville, on the River Guadalquiver, was a commercial port of great importance at the period when Spain was the chief colonial power in Europe; but during the eighteenth century the river was much neglected. It has many windings, the water is at all times very turbid (sometimes holding 4 per cent. of solid matter), and shallows were formed which greatly interfered with the navigation. The chief bends in the river were at Torno de la Merlina (10,000 metres in length), Torno del Borrego (17,600 metres), and los Jeronimos (18,000 metres), and by cutting straight channels respectively 600 metres, 1,600 metres, and 5,500 metres in length and 100 metres in width across these bends, the distance from Seville to the sea has been reduced by no less than 28 miles, and the minimum depth of water, at low tide, increased from 4 feet to 17 feet. In 1862 vessels of 200 tons could with difficulty reach Seville, whereas now vessels of 2,000 tons load and unload at the quays. When cutting these new channels it was found that retaining-walls built parallel with the stream were frequently carried away by winter floods, but the system having been adopted of projecting at short intervals transverse walls into the stream a little below the water-level, these checked the current and caused such a deposition of the floating solid matter between them that a perfectly sound channel has been formed. The last of these works was completed in 1889. It reduces the distance from Seville to the sea to 54 miles, and has increased the rise of tide by 7 feet 6 inches since 1862. Between July 1st, 1888, and June 30th, 1889, the exports by river amounted to 163,755 tons, and the imports to 155,609 tons. The river is navigable for only a short distance above Seville, and mill-dams which intercept the stream preclude all navigation above Tocina. By a singularly fortunate disposition of some rocks at the mouth of the Guadalquiver, the depth of water on the bar has remained constant from time immemorial.

On the same coast is the tidal estuary which goes by the name of the Huelva river, and is formed by the junction of the Rio Tinto and the Odiel at about 4 miles below Huelva, and 8 miles from the sea. The Rio Tinto Company and the Tharsis Company have built extensive quays on the River Odiel for loading their ores, and so also have the companies owning the railways from Seville and from Zafra. Another private quay has also been built at San Juan del Puerto by the Buitron Mining Company. The exportation, chiefly of copper pyrites, exceeds 1,000,000 tons per annum.

The River Guadiana which, as it nears the sea, becomes the frontier between Spain and Portugal, is navigable for large vessels for 36 miles from the coast. On the Portuguese bank it has double the traffic which there is on the Spanish side, owing to the large shipments of copper pyrites from the well-known mines of Santo Domingo. From Spanish ports about 25,000 tons of pyrites are annually exported in English vessels from the mines of Los Pastos

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and Santa Catalina, besides which the coasting trade averages 28,120 tons, and the exclusively river traffic (consisting of fish, building-stone, and flour) amounts to 13,300 tons. Vessels of 1,000 tons reach the wharf of the Los Pastos mines, but the coasting vessels do not usually exceed 60 tons, although the minimum depth of water is 27 feet. No works have been constructed of any kind to improve the conditions of the river and the upper portions of the river are not used for navigation.

The Tagus is the next large river. It crosses Spain and Portugal from east to west, discharging its waters into the Atlantic at Lisbon. During the reign of Philip II. it was sometimes utilized for the conveyance of war materials from Toledo to the frontiers of Portugal, and towing-paths and other minor works were executed under the direction of the notable engineer Antonelli, but these were subsequently neglected and gradually disappeared. In 1855 some similar works were commenced, but it was found that the conditions of the river made any useful navigation impossible. The stream forms a succession of broad open expanses with a fair depth of water alternating with narrow gorges and with rapids (of which there are nineteen between Toledo and Portugal), where the water is only 2 feet deep, and the current runs at the rate of from 5 to 9 miles an hour. At the bridge of Alcantara the waters rise frequently during floods to a height of from 35 to 65 feet, and sometimes even to 100 feet above their usual level, and, moreover, there are several mill-dams, solidly constructed across the stream, which interfere with the free navigation. The population on the banks of the Tagus is scanty, and the river could only be rendered navigable at an enormous expense.

The conditions of the River Douro resemble those of the Tagus, to which its course is approximately parallel, although much further north; its mouth is also in Portugal, at Oporto. In many places straggling rocks interrupt the current, and in others shallows and numerous rapids intercept the navigation, so that the only traffic is conducted in a few boats which convey small quantities of wine to Oporto, and, with great labour, return with sardines and other fish. With the exception of one landing quay at Frejeneda, where the River Agueda runs into the Douro, no works of any kind have been executed to improve the navigation.

The lower part of the River Minho forms the boundary between the Spanish province of Gallicia and Portugal. The tide rises to a distance of about 21 miles, and here the river is navigable for fishing-boats averaging 12 tons burthen. Timber is also floated down the river from forests in the interior, but no attempts have been made to better its conditions.

Round the coasts of Gallicia, Asturias, and Santander, in the Bay of Biscay, there are a large number of minor rivers which support a limited traffic over a short distance from their mouths, and the Author enumerates and briefly describes the conditions of those of Vigo, Pontevedra, Arosa, Muros, Camariñas, Betanzos, Ares, Ferrol, Cedeira, Santa Marta, Vivero, Foz and Rivadeo in

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Gallicia; of those of Navia, San Estevan de Pravia, Aviles, Villaviciosa and Rivadesella in Asturias; and of the Deva, Tina Menor, Santander, Cubas and Limpias in the province of Santander. They are mostly only navigable as far as the tide reaches, but at Vigo and Ferrol they form magnificent harbours, and the Royal Arsenal at Ferrol is the most important in Spain. It was visited by Mr. Pitt before the great war, and he remarked of it that it was worthy of being protected by walls of silver. At Aviles the river expands into an extensive back-water, and there being more than 15 feet of water at low tide over the bar, a splendid harbour might, and perhaps some day will, here be made. A large basin, 137,000 square yards in extent, has recently been constructed, which is chiefly used for embarking coal from the neighbouring mines, and it is probable that further works will soon be undertaken.

The only remaining river which need be mentioned is the Nervion which forms the important harbour of Bilbao. Very extensive works have here been constructed during the last few years in order to develop the trade of the port and the export of iron ore. River-walls which extend from the town to the mouth of the Nervion have narrowed and deepened the channel so that vessels with a draught of 20 feet can now discharge at the quays of the town; and the importance of the trade which has been created in a few years' time is evidenced by the fact that in 1889 the imports amounted to 580,155 and the exports to 3,879,816 tons. 85 per cent. of the latter consisted of iron ore, mostly for the English market, while of the imports 369,047 tons were of coal.

O. C. D. R.

The Protection of River-Banks. By G. Victor Revy.

(Wochenschrift des oesterr. Ingenieur- und Architekten-Vereines, 1890, p. 325.)

This Paper refers to the works undertaken of late years for the safety and protection of the rivers Theiss and Bodrog, in Hungary. On the former river the breaches of the bank are occasionally very considerable, and particularly while the floods are subsiding, for the upper loamy strata, previously saturated by the flood-waters, lose their cohesion and crumble away, while the more sandy strata at the foot are washed out by the low-water current, which also carries the fallen upper strata with it. The nature and design of the works necessary for strengthening the banks depend upon the character of the river and local considerations, and vary as the curves or bends are sharp or gentle in each case, or the banks are straight. Single or isolated spurs, extending far and deep into the river-bed are to be avoided, for though they may be strong enough to resist destruction by floods, they frequently cause damage in other parts of the river. Again, as the breaches of the

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banks almost always take place downwards towards the foot, very strong and heavy works are not required at the top of the bank: all that is necessary is to secure them from attack in rear. The works lying below low-water level must be firmly secured in position, and at the points subject to attack the velocity of the current should be reduced so that a silting up may take place. The rivers Theiss and Bodrog are dissimilar in character, and therefore require different treatment. On the Theiss timber is mostly used, in the form of piles, branches of trees, brushwood wattles, &c., because these are cheapest, and only a small quantity of stone is employed as it is difficult to obtain. The works are begun at low-water level by driving in rows of piles till their tops reach that level, and between the piles tree-branches are laid on one another, with their brush ends towards the stream. On these are laid wattles and brushwood, weighted down as uniformly as possible with stones until the lower layer reaches the bed, and thus the work is advanced until low-water level is reached, when the piles are connected by cross-stays, so as to form a compact whole. The part above low-water level is similarly treated, but the work is gradually lighter—that is, less compact—till it reaches the top of the bank, which is then sloped and revetted. Works of this kind have been carried out at six different points on the Theiss river, and are still in good condition. Of these, the following details are given of the works undertaken at Kenezlo and Csermely. After the great floods of 1884, the Theiss at Kenezlo had so scoured away the bank in the sharp curve below a cut in the river as to threaten the embankment behind. The depth of water on the concave bank increased enormously, while the bed on the opposite side was silted up. On the subsidence of the floods, work was commenced by driving in piles from 26 to 30 feet long, with branches of trees laid between, as before mentioned. At the end of three years it was found that the former concave side had silted up, while the current had forced a passage through the sand-banks previously formed on the opposite side. At Csermely the old bed of the river below the cut was not interfered with, and the banks of the cut were not attacked. The flood consequently discharged freely through this cut till it reached the next bend of the river, where a whirlpool or eddy was formed which changed the direction of the current, and led it on to the opposite concave bank. The trees and branches brought down by the flood and deposited on the convex side, contracted the waterway and thus increased the velocity of the stream, and made the bend still greater. The effect of this scour is shown by the fact that in a distance of 130 yards the river-depth was increased from 10 to 59 feet. For the security of the bank, piles from 1 to 1¼ foot in diameter, and 33 to 52 feet long, were driven in four rows, 6½ feet apart; and between these, as in the previous example, branches of trees and wattles were laid and weighted with stones. Altogether 620 piles and 1,300 cubic yards of stone were employed. The effect of this work,

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as obtained by measurements taken in February 1890, is that the great depth of 59 feet has been reduced to 32½ feet, thus showing that the bed had silted up 26½ feet. Moreover, the obstruction previously caused by the accumulation of trees &c., on the opposite side, was entirely removed by the current. As regards the Bodrog the conditions are different, for the Theiss runs through sandy soil and frequently changes its course rapidly in a remarkably capricious manner, but in the Bodrog the stream moves on slowly and steadily without any perceptible change, as it cannot work through the firm loamy soil confining it; the protecting works have therefore remained unchanged for years. For these works stone is mostly used as the quarries are near at hand, and as it is not necessary to go down deep into the river-bed, shorter piles suffice. There are nine points where such masonry works have been constructed on the Bodrog, and these are still in good condition. The most important are at Szomotor and Szerdahely, where little or no change has taken place during the past eight years. A plate, with plan and cross-sections, showing the works constructed at Kenezlo and Csermely on the Theiss, and at Szomotor and Szerdahely on the Bodrog, accompanies the Paper.

W. H. E.

The Blasting of the Iron Gates (River Danube).

By J. J. VAN DEN WYNGAERT.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses, February, 1891, p. 119.)

On September 15, 1890, the first portion of this great work was inaugurated by Mr. Baross, the Hungarian Minister of Commerce, who attended in person to transmit the electric current which caused a most successful explosion. The Author shows that the importance of improving the waterway of the Lower Danube was recognized even by the Romans in the time of Trajan, and the subject has since that period been constantly mooted; but owing to the want of unity among the nations inhabiting either bank of the river, the works have been from various causes delayed or hindered, and it was not until after the Crimean War, at the Congress of Paris, that the subject of the regulation of the Danube was discussed upon a basis likely to lead to a satisfactory conclusion. The Author gives an account of the various schemes which have from time to time been propounded for the improvement of the navigation, and he states that to Mr. Baross belongs the credit of the ultimate decision that has been arrived at, namely, to blast away channels in the rock, and to do without locks; the provision of which latter would have greatly impeded navigation, and would have entailed an expenditure of not less than 85,000,000 gulden

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(£7,083,333). The Author states that in the course of the next five years the following quantities of rockwork will have to be removed from the bed of the river:—

	Cubic Metres.
At Stenka	7,000
„ Izlas Tachtalia	121,000
„ Juczs	32,000
„ The Iron Gate	246,000

In addition to the above the rocks at Greben on the right bank of the stream, with a cubic content of 505,000 cubic metres, have to come away, making up a gross total of 1,360,000 cubic metres of rock to be got rid of. Assuming a uniform specific gravity for all the rock, the total weight of material is estimated at 4,365,000 kilograms (*sic*)[1], or say 436,500 double truck-loads, which would require a period of three years and four and a half months to train away. Details are given of the pile-drivers, steam-dredgers and rock-drills mounted on tripods and on barges employed on the job. The works have been begun at three different places at once. The obstruction caused to the flow of the river by the rocks, which jut out into the stream from the Servian territory for a distance of 420 metres, occasion a whirlpool with a depth estimated at 50 metres. Directly these rocks are passed, the river widens out into a veritable lake, with a width of 2,500 metres. Various improvements of the bed will have to be undertaken here, in regulating the stream, and it is intended to construct a dam with the excavated rock, and to support it with cross dams. The cost of the plant alone for these works is estimated at 2½ millions gulden (£208,333). The Author concludes with a brief statement of the advantages to navigation and commerce of a waterway for large vessels through the heart of Europe, from Holland to the furthest confines of Austria.

G. R. R.

Progress of the Works of Improvement in the Bilbao River.

(Anales de la Construccion y de la Industria, Madrid, 1890, pp. 21, 36 and 52.)

In continuation of previous reports by the chief engineer, Mr. de Churruca,[2] the *Anales* publishes an account of works subsequently executed at the expense of the local authorities. They consist chiefly in the completion of the river-side embankments. At every 75 metres on the right bank truncated cones have been built in masonry rising to above the highest level of spring-tides, and furnished with stout wrought-iron rings to which vessels in the river can secure their cables. The sea-wall at Portugalete,

[1] Milliers.
[2] Minutes of Proceedings Inst. C.E., vol. xcviii. p. 431.

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890 yards in length, has been completed with a parapet in masonry 10 feet in height, and the same in width, crowned with an ashlar cornice, which on the side of the sea is inclined outwards to throw off the waves which break against the wall. Covered sheds have been built for the receipt of merchandise, and several powerful steam-cranes have been erected. The dredging is now confined to the river-channel, in which it is estimated that 800,000 cubic metres of sand and mud brought down by the river, or driven up by the tide, must be annually removed, at an average cost of 6·7*d.* per cubic metre.

The important outside harbour has been commenced, the contract for the breakwater (1,500 yards in length) and approaches having been taken by Mr. Allard, at the price of £860,000; but the report published in the *Anales* only brings down the account of the states of these works to the 1st July, 1889. They are being executed with a large subvention from the State; the Provincial Deputation contributes £102,800, and the Town Council of Bilbao £42,000, both sums payable in twenty annuities, and extra harbour dues of 2½*d.* per ton are to be levied in aid of the work, which will allow of money being raised by loan. The position of the breakwater was buoyed on the 21st September, 1888, and on the same afternoon the Ministers of Public Works and of Marine inaugurated the works with great solemnity, and launched the first stone (previously blessed by the church) into the sea.

Large quarries have been opened by the contractors on the hill-side adjoining the breakwater, and along the front of them they have built a road, or terrace, 40 feet wide and 450 yards long with lines of rails connected by an embankment 130 yards in length, and a bridge over the Bilbao-Las Arenas Railway, with the shore end of the breakwater at a height of 27 feet above low water. They have also provided three steam-barges, each of 300 tons, upon which the large blocks, which are to form the lower layers of the work, will be conveyed to their destination, and then lowered to their proper site. The foundation and the outer layers are to be built of large artificial blocks, the making of which has been also commenced. Within the breakwater there will be anchorage and shelter for the largest ships, the depth of water being from 40 to 50 feet; and it is noted, with satisfaction, that the ministers, who came from Madrid to inaugurate the harbour works, took the same opportunity also to celebrate the commencement of the construction of the three large armour-clad war-ships which Messrs. Rivas and Sir Charles Palmer are now building in their docks at Bilbao, and of which the formidable armament is also to be supplied from the arsenal they have erected on the spot.

O. C. D. R.

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The Bilbao Arsenal and the Launch of the Cruiser "Maria-Teresa."

(Anales de la Construccion y de la Industria, Madrid, 1890, pp. 265–268.)

In October, 1888, Messrs. Rivas and Sir Charles Palmer commenced the construction of the arsenal and dock at Bilbao, at which they have undertaken to build and equip for the Spanish Government, with Spanish materials and workmen, the three powerful iron-clad cruisers, "Maria-Teresa," "Vizcaya," and "Oquendo," the first of which was launched in the presence of the Queen Regent and her ministers on the 30th of August, 1890. The armament of each of these ships is to consist of:—

Two 33-ton guns of 12-inch bore and 35 feet in length; weight of projectile, 704 lbs.; weight of charge, 352 lbs., to pierce an iron plate 20 inches thick at 4,000 metres distance. These will be mounted in turrets at each end of the ship.

Ten 14-centimetre guns, 17 feet long; eight Nordenfeldt rapid-firing guns, bore 5·7 centimetres; eight Hotchkiss revolving guns, bore 3·7 centimetres, two Gatlings, bore 11 millimetres, and eight tubes for projecting torpedos. These are all to be made on the spot, with the exception of the Nordenfeldts and the Gatlings, which are to be supplied from the gun factory at Plasencià.

The buildings composing the establishment are very extensive, and cover a space of 52 acres. The dry dock, 376 feet long by 82 wide, is encircled by piles formed of large cast-iron cylinders, weighted, when driven, with 100 tons, and filled up with scoria and cement. Around it the workshops are built, comprising in separate compartments all the machinery which is required for building war ships. The artillery department is separated from the rest by a short distance. It consists of four galleries 275 feet in length, the two inner ones 50 feet, and the two outer galleries 33 feet in width. Two thousand four hundred men are employed on the works, of whom one hundred and sixty are English and the rest Spanish. The works are lighted by electricity.

The building of the "Maria-Teresa" commenced on the 24th of July, 1889, and she is to be completed and armed by the 1st of December, 1891. The launch on the 30th of August, 1890, was witnessed by an enthusiastic crowd of fifty thousand persons, and it was effected without a single hitch.

O. C. D. R.

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The Ports of Italy. By Domenico lo Gatto.

(Il Politecnico, 1890, p. 217.)

The ports of Italy, situated upon an almost tideless sea, differ essentially in all features of design and construction from all tidal ports, such as those on the Atlantic or the North Sea. In this respect nature has favoured the latter more than the shores of the Mediterranean. The ports of most world-wide renown, where commerce is most fully developed, are situated on river estuaries where the ebb and flow, in their natural course, or regulated by embankments and docks, ensure and maintain the existence of the navigable water-area by the systematically repeated scour, and assist the progress of vessels entering or leaving the port or floating into dry dock. With comparatively few exceptions, ocean ports are thus situated on estuaries, the river constituting the roadstead or outer port, and the port itself comprising a series of docks. Being sheltered from the direct effect of storms, the action of the waves is in most cases of little importance, and large breakwaters are unnecessary.

In the Mediterranean, where the range of ordinary tides is only 8 to 10 inches—rarely exceeding 12 inches—where violent gales are frequently experienced, and where the bays are mostly but shallow indentations and the rivers discharge through sandy deltas and shifting channels, with currents decreasing in force as they spread towards the sea, and thereby tending continually to silt up the waterway, the estuary port is practically impossible. The only places in Italy that can in any way be considered under this category are the canal ports, which are all of very limited accommodation.

The only currents in the Mediterranean which in any way affect the existence or maintenance of a port—with the exceptions of Venice and Messina—are those occasionally produced by any prevailing wind. The "littoral current" so often referred to is not sufficiently powerful to carry in suspension any but the very finest matter. The velocity of the current does not exceed 3 or 4 miles in 24 hours, and its average distance from the shore is three miles (increased to 6 miles near headlands and to ten or more across bays): while—following the law of river-flow—its velocity decreases both laterally and vertically, so that at a depth of 13 feet no motion whatever is perceptible. The essential agent in the formation of sandbanks and bars is the triturating and upheaving action of the waves upon the shelving shore; and it is therefore mainly with the waves that the designer of an Italian port has to deal.

The usual formation adopted is to construct an "outer port"—where the waves spend their force—and an "inner port" or harbour, with quays, docks, and other necessary structures. Many ancient ports—such as Genoa, Leghorn, Civitavecchia and Naples

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—have grown up piecemeal, without systematic design: but generally speaking Italian ports may be classified under three heads, viz.:—

1. Basin-ports or harbours.
2. Dock-ports.
3. Canal-ports.

The majority come under the first category, being formed in natural or artificial basins—small bays being utilized as far as possible, and extended by masonry piers and breakwaters. Most of these harbours have only one entrance, and are protected by two piers; that to leeward (*sottovento*) being generally unimportant, while that to windward (*sopravento*) is extended to cover the furthest point of prevailing winds which would affect the water up to the end of the leeward pier. There are, however, two notable examples of harbours with two mouths, viz., Leghorn and Civitavecchia, as well as Licata, in Sicily. At Salerno and Molfetta and other places the second mouth has been closed, and the same process is required at the other three places named. At the present day, when steamers and tugs have rendered the old wide harbour entrances unnecessary, the most important requirement is tranquillity of water inside the harbour, and for this purpose the old type of exposed port with two entrances may be considered as practically abandoned.

Where there is not sufficient draught of water alongside the quays, or where space has to be especially economised, short piers or double-faced quays (*ponti sporgenti*) are built out at right angles with the shore.

The type of dock-port is at present not frequent in Italy, the most notable examples being Savona and Leghorn.

The canal-ports—which, as stated, are of very limited accommodation, being suitable only for small coasting vessels—are mostly on the Adriatic coast, viz., Magnavacca, Ravenna, Ceroia, Cesenatico, Rimini, Pesaro, Fano, Sinigaglia, and the five ports of the Venetian lagoon: Malamocco, Chioggia, Lido, Sant' Erasmo, and Treporti. The only ports of this kind worth mention on the Tirrenian coast are Fiumicino and Viareggio. The channels at Malamocco and Lido (referred to later) are the only ones available for large vessels. Of the above mentioned ports, three are on artificial canals and the remainder on natural streams. The type of construction is two parallel or slightly divergent piers extending to a sufficient depth of water for the draught of vessels to be provided for. With the small range of tide, however, and sluggish streams, the solid matter brought down is continually silting up the mouths of these ports, and involves incessant dredging. At Pesaro the old channel having become entirely choked up, a new cut has been made. In two cases the scour is assisted by a large reservoir or basin at the inland extremity of the port, viz., at Cesenatico (26 acres) and at Magnavacca—where there is a fine natural catchment basin of 495 acres.

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Following this general description of the character of Italian ports, the author proceeds to a succinct description of the more important places.

Savona: Natural bay with two small piers. Consists essentially of two docks, with extensive siding accommodation. Depth of water in outer port and in new dock—26 feet. Chiefly exposed to winds N. and E.

Genoa: The chief port of Italy. A semi-circular bay with important defence works of irregular plan, arising from successive development of the port. Depth of water at quays averages 20 to 23 feet. Length of quays available for large vessels—7,321 yards; ditto for smaller vessels—1,972 yards. When completed, the port will comprise 12,260 yards of quay accommodation. There is a complete system of sidings, connected with three stations; also hydraulic installation comprising forty-two 1½-ton travelling cranes, and three fixed 10-ton cranes—the water compressed to 50 atmospheres by two 250-HP. engines and four accumulators. There are also steam and hand cranes, and ten pontoon-shears capable of lifting from 20 to 70 tons. The warehouse accommodation is not yet fully developed, but is still in course of construction. The repairing arrangements are also being extended, the large dry docks having a length of 722 feet, breadth 82 feet, and depth 29 feet. Up to the close of 1888 the amount expended on the various works was:

	£.
Piers, quays, and other seaworks	1,370,000
Sidings, cranes, gas, &c.	537,500
Custom house, warehouses and buildings	605,300;

about £500,000 being still required, bringing the total expenditure up to about £3,000,000.

Leghorn is a harbour with two entrances and with docks. The anchorage being exposed, a long curved breakwater was constructed some years back. The harbour was formerly very shallow, but the southern end is now excavated to a depth of 29 to 33 feet, decreasing to 23 feet at the northern end. Good repairing accommodation, including dry dock 443 feet long and 24 feet 3 inches deep.

Civitavecchia, near the mouth of the Tiber, dates from the time of Trajan. It is formed by a small bay with two piers, and on the north side a dock constructed in the year 1500. The mouth is protected by a breakwater, giving an entrance at each end. The south channel only is available for large vessels, the northern entrance having only 18 feet of water. There are neither available quays nor repairing accommodation; but in view of the position of the port in relation to Rome it is probable considerable improvements will shortly be carried out.

Naples[1]*:* This port comprises two harbours, the military port and the commercial port, together with the outer roadstead. The

[1] Minutes of Proceedings Inst. C.E., vol. cii. p. 360.

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depth of water in the latter is from 40 to 100 feet; in the old commercial port 29 feet 6 inches to 16 feet 6 inches, and in the new commercial port, minimum 26 feet.

Brindisi is an entirely natural harbour. The roadstead has been improved by the construction on the northern side of a causeway 1,473 feet in length to the small island of S. Andrea, and the extension of a breakwater 843 feet long from a spur of the same island. The outer port has an area of 536 acres of good anchorage, and there is a further fairly protected roadstead of 650 acres. The port is the principal point for Oriental traffic and passenger service. It is chiefly exposed towards the east.

Bari has a small ancient harbour, facing east, and a large new port on the north side of the town exposed chiefly from N.W. to N.E., with extensive quays and having a depth of water varying from 33 feet to 20 feet.

Ancona: Port entirely artificial, formed by two long piers connected at base by quays. It is exposed to west winds, and the sea is frequently very rough, waves 6 feet high rolling into the harbour. The water is shallow, only one-fifth of the area having a depth of 26 feet, a further two-fifths being 16 feet deep, and the remainder about 10 feet. Few large vessels, therefore, are able to moor near the quays, but considerable excavation is now in progress.

Venice, being protected from the sea by a long belt of land, has no need of defence works, and simply comprises anchorage, quays, and docks. The Canale della Giudecca, with a length of $1\frac{1}{4}$ mile, an average width of 1,000 feet, and a depth of water of 24 feet 6 inches to 28 feet, is the chief roadstead, but there is not much quay accommodation for large vessels to moor close alongside. The dock-basin (*stazione marittima*) has an area of 2,300 feet by 623 feet, with a depth of 26 feet, and is well furnished with sidings and hydraulic cranes. The tidal range at Venice averages 2 feet 3 inches, but with the scirocco the water has risen as high as 4·37 feet above the mean level, while under opposite conditions it has sunk to 4·82 feet. The duration of ebb tide is considerably less than that of the flow, and the velocity, therefore, much greater. No very reliable data are yet available on the subject, and there is considerable variation in the tide, but the approximate average velocity is nearly 5 feet per minute. The present channel through the lagoon to Malamocco, a distance of eight miles, has a width varying from 150 feet to 330 feet, and an average depth of 28 feet: but as the distance from Venice to the sea by this way is very inconvenient, extensive works are now being carried on at Lido.[1] These works will also absorb the ports at Sant' Erasmo and Treporti into one channel, 3,280 feet in width, the depth of which is expected to become 28 feet by natural scour, and extending out to sea between piers 11,320 and 9,350 feet in length respectively.

Messina (Sicily): An entirely natural port, formed by a deep

[1] Minutes of Proceedings Inst. C.E., vol. c. p. 189.

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circular indentation of the coast with a narrow opening towards the north, and having a depth of 130 feet to 200 feet. At present, however, there is not a great length of quays in sufficient depth for large vessels. The tidal effects are very irregular and peculiar, owing to the position of the port on the strait of the same name, connecting two distinct parts of the Mediterranean. Low tide in one corresponds nearly with high tide in the other, and the effect at Messina depends chiefly upon the wind, which causes one tide or the other to prevail. The ebb tide lasts only 1½ to 2 hours, sometimes even less; the flow, therefore, generally 10 to 10½ hours, while the range varies from only 2 inches to 13 inches.

Catania: A much exposed port, in the gulf of the same name. It is enclosed by one pier, 3,600 feet in length, and has a depth of water varying from 26 feet to 50 feet. The port accommodation is not yet much developed.

Palermo is entirely artificial; average depth, 23 feet. Formed by two piers enclosing a long shallow bay.

Trapani: A natural port, with one pier. Exposed partly to south winds. Depth of water, 23 feet to 80 feet; anchorage, 900 yards in length and average 530 yards wide; quays, 766 yards long, with depth 24 feet 6 inches to 16 feet 6 inches, and further length of less depth.

Girgenti (Porto Empedocle): Entirely artificial. Formed by two long curved piers, of which the windward is 3,480 feet long. Depth of water at entrance, 26 feet to 29 feet. No warehouses yet constructed or quays in sufficient depth of water.

Licata: An entirely artificial port, still in course of construction, but badly located, being rapidly silted up by a river close to the harbour mouth. In the course of ten years, the depths of water in various parts of the harbour have been reduced 8 or 10 feet, and in one instance 15 feet. It is now proposed to close that one of the two entrances to the port which is nearest to the river.

Cagliari (Sardinia): An entirely artificial port, not yet by any means completed, and still very much exposed. Average depth of water 24 feet 6 inches; 820 yards of quays with depth of 28 feet, and 380 yards with depth of 13 feet.

The Author remarks, in conclusion, that while much has already been done, since Italy became a united kingdom, in the improvement of the ports, much remains to do to ensure the safety of the harbours and to develop the means of quick handling, storing, and transit of goods. The old harbour mouths are far too wide and exposed for modern requirements, the entrance to the inner port not requiring to exceed 165 feet in width. The development of Italian ports is necessarily limited by the overstrained national finances, but the sum of £2,525,000 is at present allocated to the work by a vote of the Chambers in 1889.

P. W. B.

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Notes on the Employment of Water under Pressure in founding the Quay-Walls of the Outer Harbour at Calais.

By M. BAILLY.

(Compte Rendu des Travaux de la Société des Ingénieurs Civils, October, 1890, p. 582.)

In the execution of the new harbour works at Calais, the foundations of the quay-walls for the outer harbour have been sunk by means of water injected under pressure, a method which has been attended with the most satisfactory results as regards economy and rapidity of execution, and which the Author believes to have been here introduced for the first time.

The quay-walls are founded in a very fine and movable sand, easily loosened by water; and, after some preliminary trials, which proved that piles could easily be sunk by a jet of water directed beneath them, the experiment was extended to the sinking of great blocks of masonry built upon a timber curb. The experience gained in these further trials was so far reassuring that the system was then adopted on a large scale for the sinking of the quay foundations and also for the driving of piles and sheeting.

The foundations are carried down to a depth of 8 to 11 metres below the present bottom of the basin, provision being made for the subsequent dredging of the outer harbour to allow vessels of the deepest draught to lie alongside at low water.

The quay is founded upon a series of square wells built of rubble masonry upon a curb or base of strong concrete. The outer surfaces of these square cells are vertical throughout, while the central shaft is octagonal in form and splayed outwards at the base, so that the walls come to a sort of cutting-edge, which, however, has a width of 1 metre, corresponding with the width of the concrete shoe. In general, the wells are 8 metres by 8 metres in outside dimensions, the octagonal shaft being 4 metres in diameter, and the wells are sunk side by side in the line of the quay wall, leaving spaces of 0·4 metre between them. In sinking the series of wells, the first, third, fifth, &c., are first got down, and then the intervening ones, and lastly the intervening spaces of 0·4 metre are excavated by the water-jet and filled with concrete, which dovetails the whole series together by filling two pairs of grooves, which had been formed in the sides of the contiguous masonry wells.

The process of sinking one of these wells is as follows:—The masonry cell is first built *in sitû* to a height of 4 metres, and the well is sunk by injecting water under the cutting-edge by means of wrought-iron pipes carried down through the central shaft, and splayed outwards so as to direct the jet upon the sand beneath the cutting-edge. Thus loosened, the sand is brought up by a centrifugal pump, whose suction-pipe descends in the centre of the

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shaft, and draws sand and water from the bottom of the conical cavity, which is gradually formed by the disengagement of the sand around its sides. The pumping-machinery for the sinking of the wells is mounted on wheeled trucks, which run upon a line parallel to the line of wells. For the water-jets, four Tangye pumps are employed, and are supplied with steam from two small vertical boilers, while the centrifugal pump is driven by a separate portable engine and boiler. The wrought-iron pipes, by which the water-jets are delivered, are twelve in number, and are divided into four groups, the three pipes of each group being connected with one of the Tangye pumps by flexible rubber tubes. The jets are so directed around the cutting-edge as to excavate the sand regularly and to correct any tendency of the well to deviate from the vertical in sinking, and in general the deviations are almost insensible.

Some difficulty was at first experienced in the working of the centrifugal pump, owing to the settlement of the sand in suspension in the suction-pipe, which tended to choke the valve at the foot of the pipe whenever the pumping was temporarily stopped. This was remedied, however, by attaching to the valve-box one of the wrought-iron pipes through which a jet of water was at such times delivered into the valve-box just above the valve, and by means of the circulation of a continuous stream of water the deposit of the sand was prevented.

On the average the sinking of a well to a depth of 4 to 4½ metres was accomplished in twelve to fourteen hours, which is equivalent to about 20 cubic metres of excavation per hour.

When the well had been sunk to a depth of 4 metres, bringing its top to the level of the ground, the masonry was carried up for a further height of 4 metres, and the operation of sinking was then resumed.

In a bed of clay the operation is more difficult and much more tedious; but the system was successfully employed to sink through beds of about 1 metre in thickness. It was also applied to the sinking of wells of smaller dimensions, 4½ metres by 4½ metres and 4 metres by 4 metres. In these cases the rate of sinking in sand was much faster, and it became more difficult to prevent the well from deviating from its true position.

T. C. F.

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On the Prevailing Winds and Silting-Action in Sea and Lagoon at Venice. By DAVIDE BOCCI.

(Annali della Società degli Ingegneri e degli Architetti italiani, 1890, pp. 119, 203.)

The Author premises that his observations are founded especially on studies on the Brenta, Bacchiglione, Gorzone, Sile, and other rivers of this part of Italy. The first portion of the memoir comprises a summary of general considerations and hydraulic formulas. The second portion refers to winds and currents.

On the Venetian coast the N.E. wind prevails for six months in the year, and this is also the quarter of the most violent gales. The prevailing winds produce not only waves but temporary currents; and although the littoral current passes sluggishly along the coast at a distance of 2 or 3 miles, its effect is often locally diverted by the wind, as well as by mingling with flood waters from the Po delta. During the prevalence of N.E. winds the water level in the lagoon from Brondolo to Le Tresse—the inlet of the land drainage—is frequently raised. This is very apparent at the sluices at Brondolo, where, when the gates are open, the water flows from the river to the lagoon except when strong N.E. winds reverse the current. The force and direction of the prevailing wind in times of river-flood materially affect the extent of solid matter deposited on the shore. Carrying much heavier matter in suspension, the river-current impinging on the littoral current, when the latter is sufficiently backed by a N.E. wind, is checked and deflected. The silting naturally takes place firstly on the leeward side; but the relative and varying force of the two currents constantly affects and determines the direction and depth of the channel. At Chioggia, where the current from the lagoon counterbalances that from the Brenta, the shore-line remains practically unchanged; but from this point to Ca Manfrin and Fosson the land is extending at varying rates, attaining at the latter point its maximum average advance of 43 feet per annum. The advance is apparently proceeding now at a more rapid rate than formerly. The deltas of the Po, the Adige, and the Brenta and Bacchiglione are all closely adjacent and almost coterminous; in fact, the silting action of the former may be said to absorb the effect of the smaller rivers, and certainly no improvement of these can be permanently effective without regulation of the channels of the Po. The varying direction of the coast line with respect to the prevailing wind is obviously a material point in studying the progress of marine silting. From the mouth of the Piave to Punta della Maistra, a distance of 50 miles, the Venetian shore forms a semi-ellipse, the northern portion of which, from the Piave to Lido, lies nearly parallel with the prevailing winds; the middle portion, from Lido to Chioggia, at an approximate angle of 45°; while along the southern end the same wind blows straight towards shore. Under the effect of this wind the maximum

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deposits of suspended matter naturally strike this portion of the coast, and it is precisely along this southern end of the Venetian shore that the rivers have their outlets. The Brenta and Bacchiglione now discharge their waters by one united channel into the open sea,[1] after undergoing many alterations. The Author relates very fully the history of the former and the opinions of hydraulic experts in past times as to the effect of the outlet of the river into the lagoon. In the earliest historical times the Brenta discharged its waters into the lagoon at Venice; but so seriously did the alluvial deposits threaten the existence of the port that at various times from the 14th century onwards it was diverted successively to the lagoon of Malamocco, to Chioggia, to Brondolo, and finally, about 1565, to the open sea. About fifty years ago it was decided to connect the river once more with the lagoon near Chioggia; but the recent improvement works above referred to have restored the outlet to the sea. Flowing into the lagoon through a network of channels, continually shifting and silting up, the river current, freed from the greater part of its alluvial matter by the time it reached the main outlet from the lagoon to the sea, materially assisted the scour and improved the main channel; but at the latter stage, when the alluvial matter had reached to within a short distance of this outlet, the beneficial effect was reversed, and the current becoming more sluggish began to silt up the main channel also. But for this deposit, the tendency of the tidal scour would be to constantly deepen the lagoon. In early times the port of San Nicolo del Lido was available for the largest vessels of the Venetian fleet, but in spite of all efforts the channel gradually silted up to such an extent that in 1540 it was too shallow for even a gondola. After the exclusion of the Brenta from the lagoons the scour gradually increased the channel again to its former depth.[2]

P. W. B.

The Railways of Mexico.

(Transactions of the American Society of Civil Engineers, vol. xxiii. 1890, p. 285.)

In Vol. xxii. of the American Society's Transactions a Paper was published on the railways of Mexico, by Mr. W. Barclay Parsons, in the course of which it was stated that gradients of 4 per cent. (1 in 25) occur on the Mexican Central Branch from Tampico, to Aguas Callientes. Mr. Max E. Schmidt, M. Am. Soc. C.E., corrected this in the discussion. The ruling gradients are 1·5 per cent. (1 in 66·6) except on the two mountain divisions of 27 miles and 5 miles respectively, where the maximum inclines are 3 per

[1] Minutes of Proceedings Inst. C.E., vol. xcix. p. 429.
[2] *Ibid.*, vol. c. p. 189.

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cent. (1 in 33·3), and all the gradients are compensated for curves in conformity with a Table which is now printed. On the other hand, it was stated in the Paper that 4 per cent. (1 in 25) is the maximum incline on the railway from Vera Cruz to Mexico ("the Mexican Railway"), whereas this is correct only as far as the tangents are concerned, for the absence of all compensation on the curves virtually increases the maximum to nearly 5 per cent. Mr. Schmidt proceeded to comment unfavourably on the latter railway company having recently placed Fairlie engines, weighing over 90 tons, to run upon these steep inclines. In his opinion it would have been preferable to have added a centre rack-rail on the heavy gradients of the mountain divisions, and to have substituted Abt engines which at 63 tons service-weight develop a tractive power of 27,500 pounds, for the ponderous weight of the Fairlie engines is against them under the best of circumstances. An Abt engine, he said, on a track supplemented by a third rail, would haul 280 tons of gross train-load on 4 per cent. non-compensated gradients, and at a speed of 10 miles per hour.

Mr. Barclay Parsons accepted the correction as to the gradients on the Tampico branch of the Mexican Central, but did not think it by any means clear that the introduction of Abt engines on 4 per cent. gradients would be economical. As chief engineer of a system of lumber railways which he is constructing in the Allegheny Mountains of Northern Pennsylvania, he uses gradients frequently of 3½ per cent., and at times up to and over 4 per cent. The power he uses is a Shay engine,[1] with three vertical cylinders driving a horizontal shaft which is geared to all the wheels, tender included. This shaft is jointed so that the longest rigid wheel-base is 56 inches. Such an engine uses the whole weight for adhesion, and at a ratio of ¼ with a weight of 60 tons would develop 30,000 pounds of tractive power.

O. C. D. R.

Railways in Construction in Spain.

(Anales de la Construccion y de la Industria, Madrid, 1890, pp. 220, 246, 254.)

The works on the railway from Murcia to Granada are being continued with great activity, and locomotives already run over some portion of the line at the Lorca end. The tunnel under the pass at Hijate has been commenced, and the passage of the gorges near the station at Gor, which involves some important viaducts, one of which consists of several spans exceeding 100 yards in length, is advancing towards completion. Between Gor and Granada the nature of the ground involves many difficult and expensive works, among which are tunnels at Guadix, Las Animas, and between

[1] Minutes of Proceedings Inst. C.E., vol. cii. p. 386.

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Moreda and Iznalloz, and also the bridge over the river Fardes, which is a noteworthy work owing to its length.

The direction of the railway from Linares to the Port of Almeria has been materially modified, and its length thereby reduced from 192 to 150 miles. Starting from Linares, the new line reaches the river Guadalquiver at Torre Blascopedro, then continues up that river to Baeza and Ubeda; it then bears off to the south, crossing the rivers Bedmar and Jandulilla, and a few miles further on the rivers Salado and Guadiana, which last it follows for several miles. At kilometre 89 it reaches Chilla, and at kilometre 100 the station of Manzano. From this point it runs due south, past the Baths of Alicún de Ortega into the province of Granada, and for a distance of about 14 miles runs parallel with the line from Murcia to Granada. Guadix is reached at kilometre 140 (87½ miles from Linares), Huejena at kilometre 160, Benahadux at kilometre 228, and finally Almeria at kilometre 240.

On the railway from Jativa to Alcoy the works were being rapidly proceeded with. The most important are the bridges over the rivers Albaida, Las Estacas, Molinar, Torralva, Rafalgani, Mallols, Algar and Bufali. Those over the Albaida and Las Estacas have been completed, and the others are far advanced. The tunnels Nos. 2, 6, 7 and 8, had been completed, and No. 1 would be so shortly. The railway was expected to be opened to traffic in the course of the year.

O. C. D. R.

Construction and Maintenance of Track.

By J. A. HALL, M. Am. Soc. C.E.

(Transactions of the American Society of Civil Engineers, vol. xxiii. 1890, p. 330.)

This Paper contains an account of the points which demand attention in connection with the subject of railway track. Thus, while laying down practical rules for the preservation of a good road-bed, the writer gives suggestions and advice respecting the drainage of wet cuttings, the location of culverts under embankments, &c. When selecting timber for sleepers, he would prefer white oak, post oak, or chestnut oak, or, if pine must be used, a good long-leaf pine will last two or three years longer than ordinary pine; and above all, pine which has been bled for the resin should be carefully avoided, as it rots all over, and will often on the outside have the appearance of being sound while so rotten within as not to be able to hold a spike. Hewn sleepers will last one-third longer than sawn, but they should be of uniform thickness. They should be cut when the sap is down—preferably from the middle of December to the middle of February—and be

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allowed to season under shelter for at least one year before being laid down. Creasoting is the only satisfactory chemical process, and only open-grained and seasoned wood can be successfully treated.

"Servis" tie-plates, curved safety-spikes, bolts with nut-locks, rail-braces for sharp curves, level crossings, barbed wire fences, switches and frogs, surface cattle guards across the whole width of the line, and the "Fisher" bridge-joint are among the special appliances recommended and shown in the text by illustrations. With regard to the shape of rails, he enumerates, illustrates, and unhesitatingly endorses the recommendations of the rail-section of the American Society of Civil Engineers. The square-jointed rail gives more or less of an opening for the wheels to drop into, while the "mitered" rail, with angles of from 45 to 60 degrees, obviates this to a great extent, but on the other hand offers less springiness to the sledge-hammer blows of the passing wheel, and the writer explains at some length the reasons for his opinion that no absolutely satisfactory joint has yet been found. Great care should be taken so to handle the rails as not to bend or kink them. As a general rule when locating a railway, he says, "Follow that route which affords the easiest possible gradients for the longest possible distances, and then pass over the intervening distances with such gradients as are found necessary." Much unnecessary expense would be saved in railway construction by employing the very best engineers that can be obtained, and they should be well equipped and have plenty of time to do their work. A great mistake is made by the employment of incompetent engineers, and money spent in engineering is always money well spent; the location of a line should never be hurried.

Advice is given as to the selection and packing of ballast, the proper way of laying the curves, the maintenance of the track, the renewal of sleepers, precautions against rain and snow, &c., and the Paper concludes with some practical suggestions for the encouragement of efficient inspection and of a high standard of excellence in the performance of first-class work by all classes of workers, from the chief engineer to the lowest grade of labourer.

O. C. D. R.

The Manitou and Pike's Peak Railway. By F. H. Hastings.

(Scientific American, New York, January 24, 1891, p. 47.)

On the summit of Pike's Peak in the Rocky Mountains, at an elevation of 14,115 feet above the level of the sea, the United States Government has established an Observatory at a distance of about 9 miles from the Station of Manitou, on the Pacific Railway, which is at 7,552 feet lower level.

A railway to connect these two points has now been constructed

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and was opened to traffic in October, 1890, although it is only intended to run regular trains during the summer season. In order to overcome the steep gradient, which averages 1 in 6¼ (16 per cent.) throughout the whole distance, a rack-rail is laid in the centre between two tee-rails (weighing 40 lbs. to the yard), and the road is worked on the Abt cog-wheel system. The rack-rail consists of two continuous Bessemer steel rails made up of parallel bars, set 1⅜ inch apart, each containing seventeen teeth, or cogs, in their length of 80 inches, and held in position by means of die-forged steel chairs, secured to the sleepers by wood-screws. The parallel bars vary in weight from 21 to 31½ pounds per foot, the heavier bars being used on the steeper portions of the incline.

In order to prevent the track from sliding downwards on the passing of the trains a very thorough system of anchorage has been adopted, one hundred and forty-six anchors being used varying in distance one from another according to the steepness of the incline, from 200 to 600 feet. Some of these consist of steel straps, secured at the lower end to the chairs, and at the upper end to a strong pin 2 feet long and 2½ inches in diameter, which is leaded into the solid rock under the road; but where there is no rock available, a steel bar is fixed to the lower side of the cross sleeper, and held in its place by means of a piece of stout oak timber, which is carried downward at a steeper incline than that of the road until it thrusts against rock, or against another block of oak timber.

Each engine is of 200 HP., weighs 26 tons, and is capable of drawing or pushing two carriages up the incline. In descending, the cylinders of the engine are used as air-compressors, a stream of water being kept running into them continually to keep them from heating. By controlling this compressed air, the speed of the train is regulated. The engines are built to stand level on a 16 per cent. incline; there are three sets of double pinion brakes on each engine; the two back sets furnish most of the power for ascending, while the forward set are principally used to apply brake power. The two front sets of pinions have a peculiar steam-brake connection which locks them instantly, and the back pinion has a hand brake connection which is capable of stopping the whole train in a few seconds' time on the heaviest incline.

The carriages are handsomely fitted with the sides and ends as far as possible of glass so as to allow of the scenery being observed. The seats are constructed so as to be level when on the 16 per cent. incline. The trip from Manitou to the summit occupies an hour and forty-five minutes, the trip down half-an-hour less. The maximum speed is 8 miles, the minimum 3 miles an hour. The cost of constructing the entire road was about £100,000.

O. C. D. R.

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Railway from Reichenhall to Berchtesgaden.

By GUSTAV EBERMAYER.

(Zeitschrift des Architekten und Ingenieur-Vereins zu Hannover, 1890, p. 381.)

This line was opened for traffic in the autumn of 1889, and was constructed as regards details in accordance with the practice followed generally throughout Bavaria for local railways. The district passed through is one which, on account of the mountain scenery and of the saline baths at Berchtesgaden, attracts each season a large number of tourists, and it is probable that the line would have been made much earlier had not the question of the large outlay required proved a barrier.

In 1867 there was a project for connecting Berchtesgaden with the main railway system by following the valley high road, by the Salzach to Salzburg, but the consequent entry into Austrian territory, and the Customs complications which would have arisen therefrom, led to its abandonment in favour of the only alternative route, viz., by making a connection with Reichenhall, the course of the latter, however, being through a very mountainous district. The amount then estimated to be required for its construction was £402,850, or about £32,410 per mile, the length being about 12·43 miles. This amount was, however, deemed so considerable, that the idea was abandoned and not revived until nearly twenty years later. Various projects of about the year 1884 are described by the Author, but it was not until 1886 that the line as constructed was definitely decided upon. The question of gauge and also of the use of a rack rail upon the steepest portions occupied considerable attention, but eventually the normal gauge of 4 feet 8½ inches was adopted, and laid in the ordinary manner as an adhesion railway.

A very detailed account is given of the construction of the line, which is about 11¾ miles long. The minimum radius adopted was 590 feet, but this is only at one or two exceptional points, the minimum elsewhere being 656 feet, and the least length of straight between the reverse curves is 98 feet. The longitudinal section, of which a diagram accompanies the Paper, shows by a dotted line the grades originally contemplated, when it was proposed to use a rack rail, and by full lines the grades of the line as constructed. It is divided into three main inclines, viz., a length of 1·05 mile, between Reichenhall and Kirchberg of, for the most part, 1 in 100; a length of 3·54 miles, from Kirchberg to Hallthurm of 1 in 25; with the exception of a short piece of level for the station of Gmain and a short length of 1 in 28·57, and a length of 7·15 miles between Hallthurm and Berchtesgaden, with a ruling gradient of 1 in 50. The geological formation of the district is described. The rocks near the Reichenhall end are principally of mountain limestone, and at the Tristramberg of clay, so insecure as to necessitate a tunnel of 54½ yards long, in place of open cutting; cross-section

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diagrams are given of the formation in cutting and embankment. The amount of excavation was 307,380 cubic yards, of which a sixth part was rock. The course of the line in relation to the public highway and steamways is described throughout; in many places the stream being diverted to give room for the railway. For the bridges the use of ashlar was as far as possible avoided, and either carefully set rubble adopted for their construction or Portland cement concrete, the latter also being used for the bed-stones of the girder bridges, and for the voussoirs of arches up to 13 feet in span. Descriptions and diagrams are given of the principal bridges, but there are none of much importance, as the spans in no case exceed 40 feet.

The ballast required for the permanent way was on an average 1·196 cubic yard per lineal yard, and cost 1*s.* 8*d.* per cubic yard. On the steepest incline, viz., between 1·73 and 7·35 kilometres, or a length of 3½ miles, iron cross-sleepers were used and steel rails. The weight per lineal yard of permanent way, including the iron sleepers, was 257½ lbs., and the cost of the ready laid track was 18*s.* 3*d.* per lineal yard. On the rest of the line timber sleepers were used, the cost thereby being reduced to 13*s.* 8½*d.* per lineal yard. The elevation of the outer rail of the curves was calculated for a speed of 12½ miles per hour, but in actual practice the speed during the descent of the inclines is from 6¼ to 7½ miles per hour, and is forbidden to exceed 9⅓ miles per hour.

The locomotives are fitted with automatic speed indicators, and as an additional check upon the incline between Kirchberg and Hallthurm there are electrical contact makers affixed to the rails at every 546 yards, which are connected by wires with a registering clock at the Reichenhall station, so that the speed at which the trains are run on the incline can be ascertained at any time. Descriptions and diagrams are given of the various station-yard arrangements and of the buildings. There are on the new railway, commencing from the junction with the main line at Reichenhall, stations or stopping places at Kirchberg, Gmain, Hallthurm (the summit), Bischofswiese, Gmundbruecke and Berchtesgaden, the latter terminal station being the most important as regards the buildings and general arrangements.

Of the foregoing Gmain and Gmundbruecke are mere stopping points. The cost of the buildings and station arrangements was as follows, viz.:—

	£
At Kirchberg	1,105
„ Hallthurm	140
„ Bischofswiese	800
„ Berchtesgaden	5,745

Electrical communication between the stations is by telephone only, as is usual on all the Bavarian local lines.

As regards the rolling stock there are in service at the present time three tender-locomotives, with three pairs of coupled wheels and one pair of bogie wheels, each weighing 43 tons; there are

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ten passenger carriages of second and third class; two full-glazed, "prospect" saloon cars for tourist traffic in the summer season, three goods-wagons and two service wagons for postal service, &c. The Westinghouse brake is used. The total cost of the rolling-stock was about £10,000. The cost of each locomotive was £1,700, "prospect" car £450, passenger carriage £270, service-wagon £225, and goods-wagon £200.

The construction of the line, which is 11·68 miles (18·81 kilometres) in length, between the centres of the end stations at Reichenhall and Berchtesgaden, or altogether about $11\frac{3}{4}$ miles (19 kilometres), was commenced in July 1887, and it was in a sufficiently advanced condition to be opened (provisionally at first) for traffic on October 25th, 1888.

The various items of construction and their cost are given, the total amount being £72,000, or about £6,114 per mile.

D. G.

Landquart and Davos Narrow-Gauge Railway. By — JOHNER.

(Schweizerische Bauzeitung, 1890, p. 51.)

As early as 1874, when Davos-Platz was beginning to gain a reputation as a sanatorium, a normal gauge line was projected to connect it with the main line, by way of the Prættigau, the maximum grade being not steeper than 1 in 25 and the curves of not less than 9 chains radius. The estimated cost for this project, however, amounted to £500,000, or about twice the sum upon which the probable traffic would suffice to yield a fair return, whereupon the idea for the time being was abandoned.

The increasing need for some better means of communication with Davos-Platz, and also the possibility of a rival line being constructed *viâ* Chur Thusis and Filisur, whereby the traffic would be permanently diverted from the Prættigau Valley, led to the granting in 1886 by the local authorities of Davos and the latter district of a subvention for a narrow-gauge line, the terms of which were a grant of £20,000 cash, the expropriation of the requisite land, the assignment of the necessary sand, gravel and stone, and the provision of the timber required in the construction of the railway. The studies were commenced in the autumn of 1887. The general course of the line from its junction with the main line at Landquart, and after leaving the valley of the St. Gall Rhine, is through the Klus gorge, following the Prættigau valley as far as Klosters, where it turns into the Stuetzalpbach valley to Davos Culm Pass, and thence, following the left shore of the Davos Lake, reaches its termination at Davos-Platz. The height above sea-level of the line at Landquart is about 1,722 feet; at the Davos-Culm summit, it is 5,358 feet, and at Davos-Platz about 5,052 feet. It was originally proposed to adopt a rack rail

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line, with a grade of 1 in 10, between Klosters and the summit, but after a careful enquiry it was decided to make the railway an adhesive one throughout, the requisite extra length for the less steep grade being gained by zigzags along the mountain slopes opposite Klosters. The distance from the commencement to the summit is about 27½ miles, and to the terminus at Davos-Platz about 31½ miles, the maximum grade being 1 in 23·7, which extends over a continuous length of 5¼ miles. The geological formation of the district is described, and also the course of the line, which was such as to necessitate heavy works. The snow throughout the winter does not often exceed 2¼ feet in depth, but in laying out the line this snow-fall was kept in view, and cuttings consequently avoided wherever possible. The gauge originally contemplated was 2 feet 5½ inches, but that actually adopted was 3 feet 3½ inches (1 metre), with curves of a minimum radius of 328 feet and intervening straights of at least 98 feet 6 inches in length.

The estimated expense of the line was as follows, viz.:—

	£
Provision of capital	16,000
Engineering and superintendence	9,600
Land	9,200
Earthwork, retaining-walls, tunnels, bridges, works, river-works, and ballast	138,040[1]
Permanent way	40,840
Station buildings, &c.	13,360
Mechanical appliances—viz., cranes, &c.? (*Mechanische Ausruestung*)	3,720
Gates, fencing, and signals	4,600
Items in connection with working of traffic	1,080
Rolling-stock	24,000
Interest during construction	14,000
Sundries	5,560
	£280,000

The traffic it was estimated would amount to £28,000 annually The actual works were commenced in the summer of 1888; the first section was opened in 1889, and the entire length in July 1890.

A number of cross-section diagrams are given showing the line where passing through the glacial moraine, rock, &c.; also of the protective stone-work where the line abuts upon stream-courses, and of the dry walling supporting the formation, in place of the natural slope, upon steep mountain slopes; cross sections are also given of the masonry retaining-walls and of the two forms of tunnels where piercing the moraine and the rock, which latter have a clear internal width of 11 feet 10 inches at rail-level, and a height of 15 feet 1 inch from the rail to the soffit. Sketches are also given of the principal bridges.

[1] In construction, this combination of items, included under the head of "Unterbau," amounted to £158,980 (3,974,500 francs).

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The permanent way is formed by steel rails of the Vignoles type, spiked to oak cross sleepers 2 feet 7½ inches apart. The weight of the rails is 47½ lbs. per yard, the depth being 4¼ inches and breadth of head 2 inches, rolled in 32-foot 10-inch lengths, and the road is laid on a 1 foot 4 inches thickness of ballast.

Diagrams are given of the type of station buildings (chalet order) and of the station yards arrangement; also of the rolling-stock, including plans, sections and elevations of locomotives, carriages and wagons. Full particulars are given of the locomotives which have outside cylinders and three pairs of coupled wheels, with a wheel-base of 8 feet 2½ inches exclusive of a single-pair bogie, and a weight of 23 tons when empty and 29 tons when in running order.

The traffic receipts are given for each month since the line was opened, up to July 1890.

D. G.

The Ventilation of Tunnels. By N. W. Eayrs, M. Am. Soc. C.E.

(Transactions of the American Society of Civil Engineers, vol. xxiii. 1890, p. 288 (2 plates).)

This Paper deals with the methods of ventilation adopted on railways in the United States, and particularly describes those employed on the Hoosac tunnel, which is ventilated entirely by a natural current of air through a central shaft, and on the St. Louis tunnel, which is ventilated mechanically by means of a central fan, with both of which the writer was connected as engineer. Some reference is also made to the conditions of ventilation of some of the principal European tunnels.

The Hoosac tunnel is about 4¾ miles long and perfectly straight from end to end. The two extremities are at the same elevation of 769 feet above the sea-level, but from each end to the central shaft there is a rising gradient of 26·4 feet to the mile (1 in 200). The shaft is elliptical in shape, 27 feet × 15 feet and 1,028 feet deep from the ground surface to the floor of the tunnel. When this was first opened for traffic with only a single line of rails, timber shields were placed at the foot of the shaft to protect the passing trains from the danger of stones becoming dislodged from the sides and falling on the line, but when in 1882 the increased traffic required a second line of rails to be laid, and it became necessary to protect that also, the ventilation of the tunnel would have been seriously affected by the use of additional shields, and the plan was adopted of closing the tunnel at the bottom of the shaft and building two spiral ventilating galleries 15 feet in diameter, starting at right-angles to the line of railway from opposite points in the tunnel each 42 feet from the centre, and winding up to a height of 70 feet before entering the main shaft. The combined

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area of the two galleries being larger than that of the shaft, they maintained the ventilation of the tunnel as it was before, and neither the abrupt turn at right-angles from the line of the tunnel nor the spiral form of the rising tubes have proved any obstacle to the air-current, fifteen minutes sufficing under ordinary circumstances to clear the tunnel and renew the air from the two extremities to the shaft. The maximum number of trains passing daily through the tunnel in 1889, with an average of thirty cars, was sixty-five, which is very near the limit which can be safely run under present conditions, and the time is fast approaching when recourse must be had to artificial ventilation unless some other motor is used than the ordinary locomotive.

The St. Louis tunnel is constructed beneath the city of St. Louis, and forms the connection between the bridge over the Mississippi river and the Union Depot at Twelfth Street and Poplar Street in the midst of the city. It is 4,095 feet in length, the two main portions running nearly at right angles to each other and connected by a curve 740 feet in length approximately in the centre of the tunnel, where the ventilating fan is placed. The steepest gradient is 1 in 75. It is really a double tunnel, for a central wall, with openings at every 25 feet, separates the two lines of rails throughout, excepting at the fan and at the Custom House. Originally air-holes through the roof were left in several places, which it was expected would suffice to keep the tunnel free from smoke and foul air, but this proved a mistake, and, moreover, loud complaints were made because of the issue of smoke into the streets, and after many experimental tests all those openings were closed and a central fan and ventilating stack were adopted.

The stack is of boiler iron, 130 feet high, 37 feet in diameter at the base and 15 feet at the top. The fan, which is 15 feet in diameter and 9 feet wide, consists of a pair of steel cones placed butt to butt and riveted together. These cones carry sixteen blades, 3 feet wide, driven by an engine of 190 HP. at a speed varying from 70 revolutions per minute when the passenger traffic is light to 110 revolutions when it is heaviest. At 110 revolutions the tunnel is cleared of smoke in four and a half minutes from the time of the locomotive passing the fan when going east, and in three and a half minutes when going west, and it has been estimated that the total amount of air requiring to be removed on the passage of each train is 2,750,000 cubic feet. The writer, however, believes that this estimate is excessive, and judges from the tests made by himself that at 110 revolutions per minute the volume of air driven up the shaft does not exceed 240,000 feet per minute. The ventilation of the St. Louis tunnel has been considered fairly good up to within two or three years, but in certain states of the atmosphere the smoke moves very sluggishly, and the air in a portion of the tunnel is very foul whenever there is a strong westerly wind. During the year 1888 an average of one hundred and sixty-seven trains passed daily through the tunnel, so that the average

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interval between the trains was about eight and a half minutes, but by June 1890 the traffic had so increased that there were several hours in the day during which one train passed every four minutes; so that increased means of ventilation will soon become indispensable.

In Europe the subject of tunnel ventilation received a great deal of attention at the opening of the Mont Cenis and of the St. Gothard tunnels, but so far natural ventilation has been found sufficient on railways traversing the Alps. The difference of elevation at the two ends of the St. Gothard tunnel is 120 feet, and the corresponding difference in barometrical pressure is always sufficient to produce a definite current from the northern or lower end to the higher southern end, when the temperature is about the same at the two extremities. Moreover the traffic through the Alpine tunnels is comparatively light.

Reference is also made to the mechanical ventilation of tunnels in England, the system in use at the Mersey railway being fully described.[1]

In the writer's opinion the hope of successful ventilation lies in the possibility of keeping smoke and gas out of tunnels rather than in removing the vitiated atmosphere, and he thinks that where the gradients are light the best solution of the problem may be looked for from the application of electricity as the motive power.

O. C. D. R.

Compound Locomotives.

(Mémoires de la Société des Ingénieurs Civils, October 1890, p. 315.)

A lengthy discussion arose on communications made by Mr. Mallet, Mr. Durand, and Mr. Lencauchez, on the compound principle of steam-expansion, and its application to locomotives. Mr. Pulin remarked that there appeared to be but one *raison d'être* in compound locomotives—the complete utilization of the expansive action of steam; and but one advantage—economy of fuel, although in many cases it is difficult to appraise it, and should be considered as the indication rather than the measure of the economy of steam. Though the question of complication is related to that of cost of maintenance, Mr. Pulin instances the compound locomotives No. 701 on the Northern Railway of France,[2] having four cylinders, with four valves. In this engine only seven valves have been worn out in the course of a mileage run of 119,000 miles, whilst in the ordinary locomotives on the same service twice as many valves have been worn out. When No. 701 was repaired in 1888 the working parts were found to be but little worn. The

[1] Minutes of Proceedings Inst. C.E., vol. lxxxvi. p. 40.
[2] *Ibid.*, vol. xcix. p. 474.

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mechanism had worked well. During the three years in which the engine has been at work it has not been interrupted by any cause attributable to the compound system. This system permits of augmentation of expansive working in locomotives, even while considerable percentages of admission are practised, and the working of the expansion-link near the middle is avoided, without neutralizing the benefit of long admissions by abnormal condensation. It appears to be sufficiently established that the employment of high pressures is not the only cause of economy realized by compound locomotives.

Mr. Polonceau maintained that it had not yet been proved that, given a compound locomotive, it was not possible to construct a non-compound locomotive to draw the same train at the same velocity, and not consuming more fuel. "I shall always," he said, "prefer the non-compound locomotive, which has the great advantage of its great simplicity, by which it conforms to the dictum of Watt: 'In everything, and above all in machinery, seek for simplicity.'" Mr. Polonceau read two communications received from Mr. F. W. Webb and Mr. Cleminson, the first in favour of, the second adverse to, compound locomotives, showing that elsewhere, as well as in France, opinion was divided. Incidentally, Mr. Webb stated that he had much simplified, in applying automatic reversing-gear to the second or low-pressure cylinder, abandoning the Joy gear. Mr. Polonceau noticed the difficulty of making comparative experiments on locomotives. One engine-driver might make a difference of 15 or 20 per cent. in fuel consumed in comparison with another.

Mr. Mallet maintained that compound locomotives had passed out of the experimental stage. He could instance several places where twenty-five or thirty such engines had been ordered at once. Comparative trials were not so difficult to make as was usually supposed. The remarkable experiments of Mr. Borodin led to the final adoption of the compound locomotive not only on the railways of South-west Russia, but on all the Russian railways, for which compound locomotives exclusively were now constructed. Many other trials had been made. On the Eastern Railway of Switzerland an engine of the Bourbonnais type had always, for more than two years, on the various sections of the railway, shown very notable economy. The Jura-Simplon Railway Company ordered a number of locomotives, some compound, some ordinary, alike in all respects except in the cylinders. Not only did the average working of the compound engines show an important economy on the average of the ordinary engines, but the compound, which showed the greatest consumption, used notably less fuel than the ordinary engine using the least. It might be taken for granted that if there were now from 1,000 to 1,200 compound locomotives, it was because the system had manifested real advantages.

Mr. Lencauchez declared that in theory the compound system could not show any economy; and he quoted instances of comparative trials in support of this assertion. "Certain engineers,"

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he said, "think that the compound system is preferable; others equally competent think the contrary." He referred to a locomotive (No. 76, on the Orleans Railway) fitted with Corliss valves (cylindrical) which had been at work, thus fitted, for two years, with steam of 10 atmospheres. The valves were in good order, and they were of "indefinite durability."

Mr. Pulin pointed out that, with a high degree of expansive working in ordinary locomotives, an important extent of condensation of steam took place which did not appear to take place in the compound engine, in which an expansion of from five to six volumes corresponded to the best practical utilization of the steam.

Mr. Du Bousquet believed that the chief element of the economy that might be expected arose from the augmented degree of expansion rendered available by the augmented pressure in the boiler, and that, as the rate of expansion depended only upon the ratio of the final to the initial volume, it could be realized in one cylinder as well as in two; and he commended the experiments of Mr. Polonceau towards a settlement of this question.

In this connection Mr. Polonceau referred to the priming of water in mixture with the steam from the boiler, as a difficulty influencing the results. Priming, he maintained, varied from 30 per cent. to 50 per cent. in locomotives; and therefore all results were false.

Mr. Collet was of opinion that the advantage derived from the compounding of locomotives was that the "very bad" distribution effected with the expansion-link for high degrees of expansion in one cylinder was obviated by the distribution of the work of expansion in two cylinders.

D. K. C.

Contribution to the History of Compound Locomotives.

By E. Brueckmann.

(Organ fuer die Fortschritte des Eisenbahnwesens, Wiesbaden, vol. xxvii. 1890.)

The rapid but steady development of the compound locomotive renders it desirable to note some important points in the history of this development, which may be conveniently divided into two periods: the first period from the earliest ideas and experiments down to the year 1876, when Anatole Mallet made his valuable series of researches with compound locomotives on the Bayonne and Biaritz railways; the second period from the year 1876 down to the present time.

The International Railway Congress, held in Paris in September 1889, recommended that experiments with compound locomotives should be instituted, on account of the importance of the subject, especially for those countries where fuel is scarce, thus showing that they did not consider the compound locomotive to be thoroughly established, but to be still in the experimental stage.

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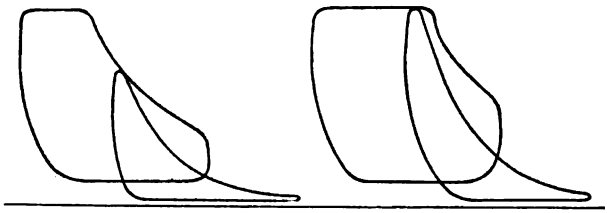
The development of the compound locomotive, during the second period, can be followed in detail from the technical journals, but it is quite otherwise with the development during the first period; only scattered notes can be collected from the above source, and also from reports of the railway companies.

The earliest known example of a compound locomotive seems to have been that of James Nicholson, an engine-fitter in the Eastern Counties Railway works at Norwich, in either 1846 or 1847. His idea was to make more use of the expansion of the steam than was usually the case in locomotives. In his arrangement, the pistons of the two cylinders were coupled in the usual way to cranks, and at right angles to each other. The boiler steam was admitted into one of the cylinders (No. 1) for nearly half-stroke, and when the piston of No. 1 cylinder had travelled quite up to half-stroke, the steam was admitted by a special arrangement of valves from the first cylinder into the second cylinder; the admission of steam in the second cylinder only amounted to one-twentieth of the stroke; the communication between the two cylinders then ceased, and the expansion continued in both cylinders, independently of

Fig. 1. *Fig. 2.*



each other. Mr. Nicholson claimed that by his arrangement the exhaust steam from only one cylinder was made use of in the blast-pipe to force the draught, whilst in the second cylinder the greatest possible use was made of the steam by very complete expansion. Mr. Nicholson communicated his idea to Mr. J. Hunter, the Locomotive Engineer of the Eastern Counties Railway Company, in 1848, and then went to the Stratford works of the same company, and in course of time a goods locomotive from his designs was built. This engine ran regularly between Stratford and Norwich for many months. Mr. J. Hunter died soon after his interview with Mr. Nicholson, but his successor, Mr. Samuel, pursued the subject with success, and in October 1850 took out a patent for a compound express locomotive. A report on this was given before the Institution of Mechanical Engineers; the title of the patent was for "Continuous Expansion Engines." The question arises, Can engines, with such a distribution of steam as in Mr. Nicholson's arrangement, be truly considered as "compound engines"? Two answers may be given to this question, as may be seen from the two diagrams showing the steam admission and expansion, *Fig. 1* and *Fig. 2*. If the admission of steam in

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the first cylinder is for *less* than half-stroke (see *Fig. 1*), then, as the second cylinder takes its supply of steam from the first during the period of expansion, the engine may be considered as truly a compound engine. But if, as in *Fig. 2*, the admission of steam in the first cylinder is for more than half-stroke, then both cylinders take the supply of steam from the boiler, and the engine cannot truly be considered as a compound engine.

Further research into the history of these early compound engines has not been successful, and the above gives, speaking generally, all that is known with certainty.

About the year 1860 a compound locomotive was proposed by Mr. E. Kemp, of the Glasgow and South-Western Railway, at Kilmarnock, from the designs of his brother, Mr. W. Kemp, of Gourlay & Co., Dundee. In this engine the cylinders were arranged with a high and low pressure on each side of the engine. Each high-pressure cylinder was divided into two single-acting cylinders with a common plunger, and between them a low-pressure cylinder, with piston fixed on the plunger, so that they together formed a tandem system, one for each side of the engine. A specially-designed double channel-valve served to effect a correct distribution of steam, giving boiler steam to the high-pressure cylinders, and exhaust-steam from them to the annular piston of the low-pressure cylinders. Mr. Kemp laid this design before Mr. B. Conner, of the Caledonian Railway, but apparently without result; eventually he took out a patent for the above arrangement of cylinders, and it has been used for marine engines.

After these early examples, the history of the compound locomotive becomes much easier to follow.

The Author proceeds to give descriptions of some of the examples of later types, with critical remarks, and the Paper is very completely illustrated, with three large plates showing the arrangements of all the early types, down to the compound locomotive by Mr. A. Mallet, of the Northern Railway of France, in 1875.

H. H. P. P.

Tugging-Strength of Railway-Couplings. By A. Pulin.

(Revue générale des Chemins de fer, September 1890, p. 135.)

On the Northern Railway of France, a falling weight of 535 kilograms, or 1,180 lbs., was employed for testing the tensional resistance of carriage screw-couplings to tugs or sudden stress, such as they are subjected to in the ordinary course of work. The height of each fall was measured, as well as the total elongation of the coupling after each fall. The trials were conducted in two ways: by commencing with a minimum height of fall, which was augmented at each fall; or by adopting a constant average fall. Table I shows the results of trials of a coupling :—

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TABLE I.

Number of Trial.	Height of Fall.	Total Elongation.
No.	Inches.	Millimetres or Inches.
1	7·9	3
2	11·8	5
3	15·8	8
4	19·7	11
5	23·6	14
6	27·6	20
7	31·5	26
8	35·5	31
9	39·4	40
10	43·3	..

At the tenth stroke, the screw was broken across at the junction with the plain portion which carried the counterweight.

Such trials by tug or shock may supply very useful indications of the quality of the materials employed in the manufacture of couplings, and of the relative strength of the pieces of which they are composed.

D. K. C.

On Ropeways, with Notes on the Plomosas Line.

By B. McINTYRE.

(Transactions of the Technical Society of the Pacific Coast, San Francisco, 1890, p. 113.)

The Author remarks that the system of transporting materials by means of wire ropeways has been thoroughly tested, the results proving that a well-constructed ropeway is as sure in its operation as an ordinary railway. It is specially adapted for the Pacific coast, where there are many valuable mining properties undeveloped on account of the ore being of too low a grade to be profitably worked on the spot by steam-power. By grinding these ores in a mill by water-power, which in many cases may be found within a few miles distance, these may often become valuable properties, and it is only a question of some means for transporting the ore, or, in some cases where water-power is not available, of providing fuel from some wooded district within reach. The Plomosas ropeway was constructed by the Author for the latter object, the upper terminal being placed 2 miles from the mines in a position where quantities of wood and charcoal were available such as would supply the mill for five years without going outside of a radius of half-a-mile from the terminal. A survey was made, from which a plate accompanying

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the paper has been prepared, showing the profile of the ground. The spans between the guide-posts vary from 104 feet to 1,066 feet, and the total distance about 10,115 feet, the greatest difference in level being 3,575 feet, between the upper and lower terminals. Hewn timber only being available, most of the frames were constructed of it, round timber being but little used. The frames of the upper terminal, the details of which are given in Plate 2, were built of timber 8 inches square. The run of the carriage for taking up the slack of the rope was restricted to 54 feet, the counter-weight gear was at the lower terminal only, and the slack of the rope was taken up when the splices were renewed from time to time. At first the intermediate posts were single, but afterwards X frames were substituted in many places. The Author remarks that during three and a half years he had no occasion to tighten up any of the frame-bolts. A four-post tower was built for the counter-weight gear 24 feet high, the weight box being 5 feet square and 3 feet deep. The transport of the rope was a serious difficulty; it was transported in ten lengths, each 2,250 feet long, each length made up into seven coils with an intermediate length of 10 feet, and each coil loaded on the back of a mule; the whole train consisting of seventy mules in all, with three men to each seven mules. An accident (described in detail in the paper) caused some delay and the death of three mules. The rope used was $\frac{13}{16}$ inch diameter steel plough-rope, made at the California wire-works of special steel from Germany, and gave a tensile strength of 300,000 lbs. A detailed description is also given of the way in which the rope was played out. The rope needs care and attention, and after trying Swedish tar mixed with boiled linseed oil, it was found that black West Virginia oil fed on to the rope by automatic lubricators was the most satisfactory, about three gallons per month being used. The cost of the work is given as follows:—

	£	s.	d.
Cost of construction of upper terminal	39	10	0
" " lower "	44	10	0
" " intermediate terminal	300	0	0
Sundries, stretching rope, etc.	52	0	0
Total cost of construction	436	0	0
Cost of ropeway material	3,168	0	0
Opening roads, etc.	373	0	0
Total for ropeway in working order	3,977	0	0

The comparative cost of wood delivered at the mill before and after the ropeway was made is as follows:—

	£
5,100 cords of wood delivered at mill before ropeway	12,670
5,900 cords delivered by ropeway	3,392
Saving	9,278

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Other expenses saved are given in detail.

The Author states that six years' experience has given him opportunities of studying the wear and tear of ropeways, and he finds that the slipping of the clips on the rope is one of the most fruitful sources of wear. He gives two woodcuts showing a clip devised to remedy the evil. The Paper is further illustrated by six plates showing the arrangement of the upper and lower terminals and other details.

H. H. P. P.

The Thermo-Siphon for Heating Railway-Carriages.

(Revue générale des Chemins de fer, September, 1890, p. 131.)

The thermo-siphon in use on the State Railways of France for warming the passenger carriages was designed by Mr. Gallet of Tours, to the instructions of Mr. Parent. The system consists of two multitubular boilers fixed beneath the frame of each carriage, one at each end, distributing hot water in multitubular structures, one in each compartment, placed transversely under the feet of the passengers. Each boiler has a central fire-box heated by peat charcoal contained in a basket, which can be put in place through a side doorway, the door of which can be securely fastened by a spring latch. Air is supplied to the furnace from below, through circular openings fitted with adjustable conical plugs, by means of which the supply may be regulated.

The foot-warmer in each compartment consists of a shallow chamber at each end, and an intermediate stratum of steel tubes, 10 millimetres, or 0·4 inch, in diameter inside, $\frac{1}{16}$ inch thick, fifteen in number. The hot water from the boiler rises into one of the chambers, passes through the tubes to the other chamber, and then back to the boiler, by natural circulation. A small cistern holds a reserve of water. The peat-charcoal fire burns slowly on the two movable grates on which it is placed red-hot, and is sufficient for eighteen hours' work consecutively. The products of combustion pass off at a temperature not exceeding 170°.

The weights and prices of the apparatus are as follows:—

	Weight.	Price.
	Lbs.	£.
1st class	1,430	56
2nd „	1,485	60
3rd „	1,540	64

D. K. C.

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Filtering-Establishments for Municipal Water-Supplies.

By Dr. Fränkel and C. Piefke.

(Deutsche Vierteljahrsschrift fuer oeffentliche Gesundheitspflege, 1891. p. 38.)

The Sixteenth Meeting of the German Public Health Society was held at Brunswick in September 1890.

The discussion was founded upon a series of theses placed before the meeting, which were as follows:—

I. All surface water must, before being used for drinking purposes, be freed from any possible sources of infection.

II. For this purpose, in all cases in which large volumes of water have to be dealt with, filtration through sand may be deemed to be the most practicable and perfect process under existing circumstances.

III. The sand-filter is not, as it has been generally assumed to be, thoroughly efficacious under all circumstances. Sand-filters are by no means capable of extracting all germs, but when intelligently worked it is possible by their means to confine the number of germs within very moderate limits.

IV. The following are the conditions for satisfactory working:—

(*a*) Good raw material (unfiltered water) so far as possible free from pollution.

(*b*) Moderate filtering speed.

(*c*) Regularity in the working of the filter.

(*d*) The rejection of the water supplied at the beginning of each filtering period.

Speaking upon these axioms Dr. Fränkel drew attention to the differing sources from which water was obtained, as surface-water, spring-water, &c. The grave consequences arising from various pollutions in water were pointed out, and the importance which has been given to bacteriological investigations by the germ theory of diseases, which for the first time afforded a clear insight into the nature of the organisms of infection. The knowledge of these germs rendered it imperative that at the outset all micro-organisms should be removed. In order to accomplish this effectually it would be necessary, in theory, to convert the water into an absolutely sterile fluid. The various means of doing this are enumerated, viz., by chemical treatment, the employment of heat, and by mechanical operations. The germs are small floating bodies, which may be entangled in the meshes of a filter and thus removed. Where large volumes of water have to be dealt with, this last process is the only one really practicable, and to James Simpson is due the credit of having devised in 1839 a method of clarifying water upon a manufacturing scale. Recent experiments have shown that, however carefully it may be used, the sand-filter is not absolutely "germ-tight." It depends largely for its impermeability upon a thin stratum of impurities and micro-

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organisms entangled in its upper layers or deposited as a net-work upon its surface, and for this reason, until a considerable volume of water has been passed through the filter, leading to the formation of this preservative layer of organic matter, the water yielded is liable to contain many germs. This net-work, however, greatly retards the passage of the polluted liquid, and in the course of time opposes such obstacles to the action of the filter that the bed becomes worked dead, and filtration has to be discontinued in order that the filtering substance may be cleansed. The Author discussed, at some length, the conditions under which the filter-bed can be used successfully for the extraction of bacteria, and it is pointed out that the number of micro-organisms in the original liquid is of very slight importance, as it becomes possible to reduce that number in a good filter-bed to from fifty to two hundred germs per cubic centimetre, whether the original number in a like volume of water was a thousand or one hundred thousand germs. Attention was called to the very sensitive nature of a filter-bed when in working order, to the derangements caused by slight changes in the pressure or the working speed, and to the dangers attending the use of the water which first passes through a new bed, and which is always very rich in germs washed off the sand, &c.

As a natural consequence of these observations, the Author maintained that the unreliability of the filter points to the necessity of adopting in all cases, where it became possible to do so, an underground supply, obtained from deep wells or springs, and he believes that waters of this kind will ultimately have an important part to play.

Mr. Piefke, in continuing the debate, pointed out that advantage must be taken of the light which scientific knowledge was now shedding upon the subject of filtration, more especially when it involved the re-modelling of the plant or the amelioration of the processes. One of the matters of extreme importance was to render the speed of filtration independent of the fluctuations in the daily rate of consumption, which varies very considerably, as was shown by a graphic diagram. For this purpose the provision of a compensation-reservoir became a matter of urgency, and the mode of calculating the capacity of this reservoir was explained. Attention was directed to the superior quality of the water yielded by covered filter-beds to that obtained from open filter-basins, and the relative cost of construction of each was considered. Diagrams and tables are given to show the comparative purity of water from open and that from covered filters at different seasons, and the great advantage of freedom from ice in the winter-time, in the case of covered beds, is insisted upon.

In the subsequent discussion it was pointed out that the theses embody most of the conditions laid down in the Metropolis Water Act, 1852. Other speakers called attention to the various methods of freeing water from iron, to the results obtained at Kiel, and to the difficulty of obtaining conclusive evidence from experiments

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conducted with filters of a small size. The congress ultimately declined to pass a formal vote upon the theses.

G. R. R.

The Water-Supply of Modern Rome. By E. HIEKE, of Milan.

(Gesundheits-Ingenieur, Jan. 1, 1891, pp. 14 *et seq.*)

Before dealing with the modern system of supply and distribution in Rome, the Author describes the arrangements by which in ancient times the water was brought into the city and was made available for the use of the inhabitants. During the first four centuries of its existence Rome possessed no public water-supply, but the citizens resorted to springs. As the population gradually became more dense, the public supply was augmented until 500 litres per head per diem, or according to some historians 1,000 litres of water per head daily, were available. To give an idea of what was implied by these figures, the Author states that the population of Rome in the year 725 after its foundation, B.C. 32, was one million, three hundred and thirty-six thousand, six hundred and eighty souls, or including the residents in the suburbs, who were also supplied from the aqueducts, a total of six millions of inhabitants. Much water was used in the public baths, which at the time of Rome's greatest prosperity, amounted to twenty-two warm and eight hundred and fifty-six cold baths, apart from eight hundred and eighty private baths. Some of the former were on a colossal scale; thus the baths of Diocletian would accommodate three thousand two hundred bathers at one time. Water-closets were in use, both in ancient Rome itself and in other rich provincial towns. According to Professor Spataro, the basins were sometimes formed of solid gold.

The first aqueduct was completed B.C. 312, and subsequently the number rose according to Frontinus to nine, according to Procopius to fourteen, or as P. Victor relates to twenty-four. The names and estimated yields of the chief aqueducts are given. The collecting reservoirs, into which the water was conducted, were called "castelli." Of these there were not less than two hundred and forty-seven in various parts of ancient Rome.

The supply was regulated by so-called "moduli," or the volume of water passing in a given time, at a known speed, through a pipe of a fixed section. The pipes used were of bronze; they were termed "calices," and, according to Frontinus, were 12 inches in length. These "moduli" of supply were not always of one fixed standard, and the various changes in unit are discussed. The water was conveyed from the castelli into the houses by means of lead or clay pipes, and the regulation of this distribution was entrusted to the official in charge of each reservoir, the "castellarius." After the fall of Rome the aqueducts were

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destroyed, and the population sank in A.D. 1377 to seventeen thousand souls. Pope Adrian I. began the restoration of the ancient aqueducts, and in the fourteenth century the city was again supplied by the Aqua Vergine and the Aqua Felice. Pope Paul V. restored the Trajan aqueduct, renamed the Aqua Paola, the water of which is, however, not potable, and till the close of the sixth decade of the present century these three aqueducts supplied Rome, with a population at that time numbering two hundred and forty thousand inhabitants.

All ancient Authors were unanimous in praising the water of the Marcian aqueduct, and it occurred to Professor Camina that this supply might be restored. He died, however, before his project was completed, and Mr. Moraldi, an architect, subsequently worked out similar ideas, until at last an English company was incorporated for the purpose of recovering this supply; the so-called Società dell' Aqua Pia-Antica-Marcia. Before the works could be commenced it was necessary to ascertain the district from which the ancient supply had been obtained, and the data for this problem were very scanty, all traces of the aqueduct itself having vanished. The Author, on the basis of the testimony of the various ancient documents, on the known cost of execution, the price of slave labour, and the length of the structure, as described by ancient writers, gives the facts by which the vicinity of Lake St. Lucia in the Apennines, 43 kilometres, as the crow flies, from Rome, was finally indicated as the probable source. Mr. Campbell was thereupon instructed to examine the springs near the lake, and he found remains of ancient masonry in the so-called second "siren" (spring), which left little doubt that the water was formerly obtained from that spot. This siren is a group of seven springs, which were collected and brought into one reservoir. The conduit from thence to the city is 53·649 kilometres in length (33·3 miles). The water is first conveyed to an ancient reservoir at Tivoli, partly in masonry channels, partly in tunnels through the rocks. From Tivoli to Rome, a length of 26·84 kilometres (16·68 miles), the water passes under pressure through a cast-iron main, 600 millimetres in diameter (23·62 inches). This main has a total fall of 108 metres, and the water flows through it with a velocity of 1·3 metre per second. The whole time required for the passage of the water from its source to the city is from eight to ten hours. This water-system was inaugurated in the presence of Pope Pius IX., on September 10th, 1870, just ten days before the Italian army breached the walls of Rome close to the works. The four aqueducts, which now supply Rome, yield a daily volume of 232,400 cubic metres (about fifty-one million gallons), an amount relatively much in excess of the supply of any other modern city.

Details are given of the methods adopted by the company of measuring the supply, as also illustrations of the special taps with glass slide-valves that are employed. The unit of measurement is the "oncia," equivalent to 1 litre of water delivered in 4·27 seconds,

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together with subdivisions of the same as low as the one-fortieth part, but the oncia of Marcian water differs from the oncia of the Aqua Vergine. The former represents a supply of 20,217 litres in twenty-four hours, and the latter a total of 40,434 litres per diem. The price of the water to householders is from six centessimi to fifteen centessimi per 1,000 litres (3·26*d.* to 8·15*d.* per one thousand gallons), but reductions are made for quantity, and traders pay 7 centessimi. The mode of house storage is explained by reference to diagrams. Chemical analyses and temperature observations on the water follow. In consequence of its composition the water causes considerable incrustations of calcic carbonate in pipes and cisterns.

G. R. R.

The Water-Supply of Hohenelbe. By — Schmied.

(Wochenschrift des oesterr. Ingenieur- und Architekten-Vereins, 1890, p. 393.)

The town of Hohenelbe, in Bohemia, is situated at the foot of the range of mountains called the Riesen Gebirge, and the springs which furnish the supply of water are about 3⅛ miles distant from the town. The quality of the water on analysis was found to be excellent, and the measured yield was 132,000 gallons daily—quite sufficient therefore for the present wants of a town containing 6000 inhabitants; but in case of further demand, other springs, some above and some below those under notice, could be drawn upon. The amount of water to be supplied is taken at 15½ gallons per head per diem for a population of 10,000, the main therefore had to discharge 155,000 gallons a day. Taking the interior diameter of the pipe at 3½ inches, the necessary head of pressure would be 403 feet, but as the difference of level between the water-surface of the highest spring and that of the main reservoir was 479 feet, this made the pressure too great for the lowest points of the main; consequently a shaft or well was interpolated in order to reduce the pressure at these points to 10½ atmospheres, the pipes being tested to bear nearly double that pressure without injury. In crossing the Elbe a trench was dug 6 feet deep, in which the flanged pipes were laid, and the whole was then filled in with concrete up to 2¼ feet above the top of the pipe. It is stated that a few hours after this had been done a fresh flood occurred, which on its subsidence, exposed some parts of the pipe, and it was found that the concrete packing had already hardened. A distributing reservoir (which serves to regulate the fluctuations in the demand for water at different periods of the day) was built at a level of from 130 to 200 feet above the streets of the town, and this holds 55,000 gallons. It was blasted out of the clay slate-rock, and required the removal of 845 cubic yards of material. The walls are built

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of hard quartz schist, and are covered with a ½-inch coating of cement. This reservoir is arched over, and on the top is a layer of earth 3¼ feet thick.

The whole network of pipes and branches is 9,537 yards long; the greatest diameter of pipe is 5 inches, the least 1½ inch. There are fifty hydrants, and at present 110 house-service pipes.

W. H. E.

The New Filter-Beds of St. Petersburg compared with those of Warsaw. By Emil Sokal.

(Wochenschrift des oesterr. Ingenieur- und Architekten-Vereins, 1890, p. 385.)

The St. Petersburg filter-beds were completed in 1889, and consist of two groups of seven and four beds each, with a total filtering area of nearly 6 acres. Warsaw at present has two groups of filter-beds, covering an area of nearly 6¼ acres, but this is only one-sixth of the total area to be provided. The St. Petersburg scheme is the property of a Company, and has been laid out with the utmost economy with a view to large profits, but the Warsaw works are the property of the City, which aims at possessing the finest water-supply scheme in Europe. The former supplies 32½ million gallons daily for a population of 930,000, or 35 gallons per head per diem, while the latter in its present incomplete state supplies 10 gallons per head daily to a population of 500,000. The St. Petersburg works have 165 miles of delivery pipes, the Warsaw works 69½ miles. The cost of water in the former is about 1*d.* per 100 gallons, and in the latter from 1½*d.* to 2½*d.* per 100 gallons, according to the size of the houses supplied and the status of the occupiers. Barracks and military buildings are supplied at half-price, and hospitals gratis. The Petersburg scheme returns a clear profit of £75,000 yearly, but the profits of the Warsaw scheme are expended by the municipality in the extension of the sewers.

In St. Petersburg the pumping and filtering-stations are close together; in Warsaw they are nearly 2 miles apart. As regards economy of working, Petersburg is the more favourably situated, as in Warsaw the water from the Vistula has to be lifted nearly 120 feet before reaching the filter-beds, but as regards cost of construction, the Warsaw beds at £3 7*s.* per square yard of filtering-surface compare most favourably with the Petersburg filters at £8 8*s.* per square yard, this great difference, it is stated, being due to the difficulty of the foundations, owing to the unfavourable condition of the soil of St. Petersburg. The Warsaw works have been in operation since 1886, and supply excellent water, the pressure between the filter-beds and the settling reservoir or clear-water basin being automatically regulated by a contrivance invented by Mr. Lindley, the chief engineer, which answers perfectly.

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As regards the St. Petersburg works, it is stated that, though early to judge of their ultimate success, both official and private reports speak of faulty construction, but it is thought that this may be remedied without difficulty. A plan of the Petersburg groups of filters, showing the clear-water basins, and the feed-pipes from the Neva to the filter-beds, accompanies the Paper.

W. H. E.

The Deep Boring at Lucknow. By R. D. OLDHAM, Assoc. R.S.M.

(Records of the Geological Survey of India, 1890, p. 261.)

An experiment of great scientific importance has lately been carried out by the Municipality of Lucknow in putting down a bore-hole to a depth of 1,300 feet in search of an artesian water-supply. As a source of water-supply the boring is a failure, but as an experiment it has been conspicuously successful. It has shown that at a depth of 1,200 feet there is water under sufficient pressure to flow to the surface. It is probable that the succeeding water-bearing strata, which would be struck by a deeper well, would yield water at higher pressure, and in any case an abundant supply of pure water can be obtained by pumping. The Author publishes in full a section of the boring received from the President of the Municipal Board, and from this concludes that the bore-hole has nearly reached the base of the alluvium, the total thickness of which is probably less than 2,000 feet. The single bore-hole put down is insufficient to decide whether the head of water comes from the northern or from the southern margin of the plains. There is a greater effective head to the north, but a more tortuous passage for the underground water. To the south the effective head is less, but if the base of the alluvium has been nearly reached, there is a more direct passage for the water, and consequently less loss of head by friction. No decision has yet been arrived at with reference to making a second boring. A deeper trial is certainly warranted.

B. H. B.

Stand-Pipe at Malden, Massachusetts. By R. S. LEA.

(Transactions of the Canadian Society of Civil Engineers, January to June, 1890, p. 75.)

Malden is one of the numerous suburban towns of Boston, Mass., having a population of 20,000. The town has been extending up the slope of the hill, demanding high-service, for the supply of which a stand-pipe or tank of wrought-iron was constructed on the

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top of Wales Mountain. The stand-pipe was more suitable than an ordinary reservoir, as the hill consisted of granite rock. It is 75 feet in diameter, 35 feet high, and the bottom of it stands 200 feet above the level of the city datum. The bottom is constructed of $\frac{5}{8}$-inch plates, 10 feet long, 6 feet wide, riveted together with a single row of $\frac{3}{4}$-inch rivets, pitched at $3\frac{1}{4}$-inch centres. The plates at the periphery are of softer material than the others, to allow the formation of a 5-inch flange all round, to which the first row of side-plates are riveted. The bottom and first side-row of plates thus united were constructed at about 3 feet above the side, and were lowered into position on the foundation. This was prepared by laying a 4-inch stratum of Portland cement-mortar —1 of cement and 2 of sand. The material was put in dry, the moisture from the foundation and bottom being considered sufficient to set it. The bottom was lowered by means of screw-jacks.

The first or lowest course is connected to the flanged bottom-plates with a triple row of $\frac{7}{8}$-inch rivets at $2\frac{1}{2}$ inches of pitch. The first and second courses are $\frac{3}{4}$-inch plates, 6 feet by 10 feet; the vertical seams being triple-riveted with 5-inch lap, and the horizontal seams double-riveted with $3\frac{3}{4}$-inch lap. The third and fourth courses are of $\frac{1}{2}$-inch plates, 6 feet by 10 feet, and all the seams are double-riveted. The two topmost courses are of $\frac{5}{16}$-inch plates, $5\frac{1}{2}$ feet by 10 feet, single-riveted, with $2\frac{3}{4}$ inches of lap. All the seams were caulked. In one of the lower side-plates, an oval manhole, 24 inches by 18 inches, is formed, with an iron cover on a seat of india-rubber.

At a height of 28 feet from the bottom, the stand-pipe is encircled by a balcony, supported by angle-bar brackets riveted to the tank, reached by a staircase.

The stand-pipe is covered by a slate roof having twelve sides supported by 12 iron trusses tied together at the centre by 1-inch iron rods. Between the trusses, the roof is supported by five rafters of channel-bar and angle-bar, across which, at $10\frac{1}{2}$-inch centres, are placed the purlins, which are of tee-iron, 1 inch by $1\frac{1}{2}$ inch, weighing 6 lbs. per yard. The roof was required, by specification, to sustain the following vertical loads:—On the purlins, 45 lbs. per sloping square foot of roof-surface; on the rafters, 50 lbs. per square foot; on the trusses, 56 lbs. The tensional stress was not to exceed 12,000 lbs. per square inch; and the compressive stress, 10,000 lbs. The roof is surmounted by a galvanized-iron ventilator or cupola.

The inside of the stand-pipe received three coats of black asphalt varnish; and the outside three coats of white lead and linseed-oil.

The stand-pipe has a capacity of 1,180,000 gallons (American), and when it is full, the water-level stands 235 feet above the city datum.

The foundation cost \$1,500, or £312 10*s.*; the roof, \$5,000, or £1,041 10*s.*; the stairs, \$500, or £104. The total cost of the

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structure complete, including the foundation, was $22,440, or £4,675. It was built under the direction and according to the specifications of Mr. M. Tidd, of Boston.

D. K. C.

The Pollution of the Isar when the River is at the Lowest Level.

By Prof. von Pettenkofer.

(Deutsche Bauzeitung, Feb. 18, 1891, p. 81.)

In continuation of investigations carried out by Dr. v. Widenmayer into the pollution of the Isar and its tributaries between Munich and Freising, the Author undertook to examine into the state of the river as respects sewage pollution at the time when the water was at the lowest possible level. These conditions were obtained after the long drought during the present winter, when the Isar had been frozen over for many weeks continuously, and when it had become so shallow that every part of it was accessible. On January 21st, 1891, three samples of river-water were taken below Munich near to the bridge at Freising, and at the same time a sample was obtained above the town at Thalkirchen. All the samples were identical in appearance, the water was clear and colourless, and was quite devoid of taste and smell. The chemical analysis was restricted to the estimation of the residue on evaporation, which most clearly indicates the contents in fecal matters, while the amount of organic substances present was obtained by treatment with permanganate of potash. Each part of oxygen required involves, it may be assumed, the destruction of twenty parts of organic substances extant in the water. The following were the results of the analyses expressed in milligrams per litre:—

Derivation of Sample.	Residue on Evaporation.	Oxygen Required.
Thalkirchen	243·2	1·37
Freising right bank . .	248·0	1·56
„ left bank . .	256·8	1·66
„ above bridge .	252·4	1·71
	Mean 252·4	Mean 1·64

The figures obtained by Dr. v. Widenmayer for the river during the highest summer-level and also for mean water-level will be seen from the following Table. The results are, as before, set forth in milligrams per litre.

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	Freising.	Residue on Evaporation.	Oxyen Required.
Flood time	June 28, 1890 .	194	2·16
	July 22, „	190	2·52
	August 2, „	206	2·15
	Mean . . .	197	2·28

The comparison between these results is very surprising, for it will be evident that during the summer floods, while the solid residue is smaller than in the winter, the amount of oxygen needed is much in excess of that required during the winter time, when the relative proportion of the excretal matter to the volume of river-water is vastly larger. The fecal polluting substances may be assumed to be equal in quantity both in summer and winter, and it would consequently be anticipated that when the river is at its lowest during the winter months, the amount of impurities present therein would greatly exceed the pollution of the river in the summer time, when the volume is much swollen, and when the proportion of river-water to sewage is so much larger. According to the gaugings of Boecking, the discharge of the Isar is as follows :—

	per second.
At lowest level	50 cubic metres.
At mean „	189 „ „
At highest „	359 „ „

The Author considers that the solid residue is mainly derived from mineral matters contained in the water furnished by springs, the relative volume of this water being much larger in the winter, when there is no rainfall, than it is in the summer, when the river is swollen with melted snow. He states also that the amount of fecal matters now discharged into the Isar produces little permanent pollution, and that it would be possible to adopt a water-carriage system for Munich, without the provision of depositing tanks and filter-beds. It is a fact, indeed, that the water is much more free from pollution when the river is low than it is when it is in flood. The salt used to thaw the tram-lines may, it is pointed out, give rise to much of the dissolved chlorine found in the river-water in the winter time. The Author shows that the two hundred and eighty thousand inhabitants of Munich could only raise the organic substances present in one litre of Isar water, at the abnormally low level of a discharge of only 40 cubic metres per second, by 7 milligrams. This amount would involve the use of 0·35 milligram of oxygen to neutralize it; whereas the organic matters present in the summer flood-water require, on an average, 2·28 milligrams of oxygen per litre, or over six times as much. In a similar way it

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is shown that the solid residue can have nothing to do with excremental pollution, and the Author asserts that he retreats from his previously expressed opinion that the sewage of Munich would have an injurious effect on the Isar, and he believes that no evil results will ensue from the discharge of the raw sewage into the river. He undertakes on a future occasion to prove that the bacteriological investigations do not support the theories of the adversaries of the water-carriage system.

G. R. R.

A Lead Pipe pierced by the Larva of a Wood-wasp (Sirex gigas).

By K. HARTMANN.

(Gesundheits-Ingenieur, January 15, 1891, p. 49.)

By reference to illustrations, the injury is shown which was inflicted upon a lead pipe by an insect that was actually found with its head in the hole pierced by it. A workman employed by the firm of Naruhn and Petsch was called in to repair a defective pipe which had been injured on a previous occasion, as was reported, by a "nail-hole" occurring in a soldered joint. This time the worm causing the mischief was found *in situ*. The hole on the exterior of the pipe was of a rounded form, 7 millimetres long by 4 millimetres wide, and the penetration was through the entire thickness of the metal. By quotations from various publications it is shown that, though of rare occurrence, well authenticated instances of similar injuries by insects are on record.

G. R. R.

The Cleansing of Sewers. By EMIL SOKAL.

(Wochenschrift des oesterr. Ingenieur- und Architekten-Vereins, 1890, p. 333.)

This Paper contains a description of a contrivance invented by the Author for the purpose of clearing the sludge in the Warsaw sewers, where the fall is too slight to admit of its being removed by the ordinary means of flushing. Recently some 25 miles of new drains have been laid in Warsaw, but out of about 900 houses in the neighbourhood only 250 drain into them, the remainder are connected with the old drains of the city, which receive also the rubbish from the houses and the street sweepings, and occasionally are so blocked with deposit as to resist the ordinary flushing power, and manual labour has to be resorted to.

The fall of the new sewers is generally sufficient to keep the bottom clean by flushing only, but there are two or three places

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where the fall is less than 1 in 1,000 and therefore require special arrangements. Warsaw also had a network of old wood and brick drains nearly three parts full of mud and deposit, which led straight to the River Vistula by the shortest cut. The new main sewer runs parallel to that river and is frequently crossed by these old drains. Connections with the new sewer were made at these crossing points, and although this arrangement undoubtedly improved the sanitary condition of the low-lying part of the city near the Vistula (for the points of discharge of the old drains into the river were closed, and the new sewer discharged at a point five miles lower down the river), at the same time it seriously affected the discharge of the new sewer.

At certain intervals dependent on the fall, flushing-gates are built in the sewer, similar to those constructed by Mr. Lindley in Frankfort and by Mr. Gordon in Stuttgart and Munich, and on the whole this arrangement answers its purpose completely, but in some places as before mentioned deposits are met with which resist the flushing power and necessitate removal by hand.

With a view to do away with this manual labour, the Author in 1889 (after an examination of the methods adopted under similar conditions in Munich, Zurich, Lausanne and Berlin), prepared the following simple contrivance. A wooden templet or mould fitted to the profile of the sewer, rests on a batten 1½ inch thick, which is pointed at the end for the purpose of penetrating and loosening the sludge. The flushing sluice above the portion of the sewer to be cleaned is closed, and water allowed to accumulate. About 6 or 10 feet lower down the templet with pointed scraper is set up: the sluice is now opened and the scraper, which is under the control of a workman, moves on and clears the deposit. If this be very solid and hard, a small shutter in the templet is opened and water sufficient to thin it is admitted, or the scraper may be used more than once at the desired spot.

W. H. E.

The Cohen Furnace. By G. Leroux.

(Mémoires de la Société des Ingénieurs Civils, Paris, September 1890, p. 462.)

The Cohen system of furnace comprises an inclined grate, at an angle of about 45°, an auxiliary foot grate for receiving clinker and ash, and a preliminary short grid at the upper end of the inclined grate, surmounted by a hopper, which is charged with the fuel to be delivered into the furnace. The uppermost grate receives the fuel from the hopper, and it can be moved with a rocking movement for the purpose of moving down the fuel, and regulating the feed. The bars of the foot-grate are in close contact for a part of their length, in order to prevent the passage of air at that place.

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At the level of the uppermost grate the upper part of the furnace is formed with a massive lintel of fire-brick, in front of which air is admitted for the combustion of the distilled gases, through an opening at each side. Air is also admitted for the same purpose from the front through the uppermost grate. A separate supply of air is admitted under the main grate through the fire-doors.

The special features of the Cohen furnace may be noted as: 1. The movability of the uppermost grate, whereby the rate of feed may be adjusted. 2. The power of regulating the production of steam. 3. The distinct supplies of air for the two phases of combustion of the distilled gases at the upper part, and the solid coke on the main grate.

The lengths of the grates are constant. The areas are varied by varying the width. The lengths are as follows:—

	Metre.		Inches.
Upper grate	0·25	or	9·85
Main „	1·00	„	39·40
Foot „	0·25	„	9·85
	1·50	„	59·10

For a width of 1 metre, the total grate-area is therefore 1½ square metre, or 16·14 square feet.

A Cohen furnace at work at the Central Electric Station, Palais Royal, Paris, was tested with semi-bituminous coal, mostly small, for a period of six days consecutively. For each 24 hours the average quantity of coal consumed was 6,908 lbs., or 288 lbs. per hour, or 12·81 lbs. per hour per square foot of grate.

The total coal consumed per day by this and the ordinary furnaces together was 1,188 lbs.; but before the installation of the Cohen furnace a total of 1,351 lbs. was consumed, showing an economy of 163 lbs. per day by the introduction of the Cohen furnace.

On the premises of Messrs. Sordes, Huillard & Co., with logwood chips, containing 55 per cent. of moisture consumed in a Cohen furnace, 1·53 lb. of water was evaporated per lb. of fuel. In another trial with chestnut wood, containing 64 per cent. of moisture, supplemented by 5·19 per cent. of coal, 1·20 lb. of water was evaporated per lb. of fuel.

The communication is accompanied by an illustrative plate.

D. K. C.

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The Moal Steam-Boiler. By J. Farcot.

(Bulletin de la Société d'Encouragement, Paris, 1891, p. 22.)

This boiler, the invention of Mr. F. Le Moal, is designed for producing a considerable quantity of high-pressure steam, from a small extent of heating surface, with a limited weight and of minimum bulk. It is a flat, rectangular, shallow chamber, placed vertically; closed at the top and bottom with plates of semi-circular section riveted to the sides, and at the ends with two flat covers bolted on, and readily removable. The chamber is traversed horizontally by short flue-tubes placed very near together, by which the water is thoroughly divided for the reception of heat. A steam-reservoir is placed above the boiler, connected to it by three neckings riveted to the upper semicircular plate of the boiler. The plate is not cut out but only perforated, to act as a strainer to prevent priming into the reservoir, as well as to retain the strength of the piece. The boiler is built into a rectangular brick seating above the fire-grate. The burning gases rise on both sides of the boiler, and are partially diverted by a partition at one side through one-half of the flue-tubes to the other side of the boiler, whence they rejoin the gases there. The whole of the gases pass through the other half of the tubes, thence they pass by downward draught to the chimney.

A boiler of this class was submitted for trial in September, 1890. The heating-surface was 113 square feet. The fire-grate was about 3 feet square, making 9 square feet of grate, or over one-twelfth of the heating-surface. In the course of five hours' trial, a pressure of from 10 to 11 atmospheres was maintained, and 860 lbs. of briquettes was consumed, at the rate of 172 lbs. per hour, or 19·1 lbs. per square foot of grate; making about 4 per cent. of ash. Water was evaporated at the rate of 884 lbs. per hour, or 5·14 lbs. per lb. of fuel.

The weight of the apparatus is about 2,420 lbs., and it has a volume of about 20 cubic feet. For higher powers, two or more such chambers are ranged in the same furnace.

D. K. C.

Results of Comparative Trials made in the United States on Water-Tube Boilers. By Chief Engineer C. H. Loring.

(Journal of the American Society of Naval Engineers, 1890, p. 580.)

Three experiments on the evaporative power of the Thornycroft and Ward types of water-tube boiler are given, and the method of conducting the trials described. The feed-water was measured by

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a Worthington water-meter carefully standardized by tests at different speeds; the record being continuous, it was possible to take the data of water-consumption at the same time as the coal and other measurements, every fifteen minutes.

The fuel used was Pocahontas coal of good average quality, that used in the trial of the Ward boiler being slightly the better; the analysis of the coal is not given.

	Ward.	Thornycroft.
Grate surface, square feet	53	38
Heating surface, square feet	2,473	2,451
Ratio of H.S. to G.S.	46·67	64·5
Weight of empty boiler in tons	11·84	9
Weight of boiler in steaming condition in tons	13·85	11
Duration of trial in hours	12	11·5
Air-pressure in inches of water	2	3
Feed-temperature	50·4	58
Steam-pressure above atmosphere	160	250
Coal per hour per square foot of grate	55·05	40·23
Refuse per cent.	4·84	7·53
Moisture per cent.	12·48	3·89
Apparent evaporation from temperature of feed at temperature of steam per pound of coal	6·60	7·53
Same from and at 212°	8·04	9·19
Actual evaporation from temperature of feed at temperature of steam per pound of coal	6·00	7·23
Same from and at 212°	7·31	8·84
Actual evaporation from and at 212° per hour per square foot of H.S.	8·62	5·51
I.HP. per 100 square feet of H.S. on basis of 20 lbs. of water per hour from and at 212°	43·10	27·55
I.HP. per ton of boiler and water on same basis	76·98	61·38

The following abstract gives the result of trials of the Thornycroft boiler at different rates of combustion:—

Air-pressure in inches of water	0·0	0·5	3·0	4·0
Duration of test in hours	2·5	11·5	11·5	1·0
Temperature of feed	52°	58·5°	58°	52°
Steam-pressure above atmosphere	250	250	250	250
Coal per hour per square foot of grate-surface	7·58	24·12	40·23	66·32
Refuse per cent.	6·11	8·04	7·53	6·27
Moisture per cent.	8·09	2·11	3·89	6·68
Apparent evaporation from temperature of feed at temperature of steam per pound of coal	10·55	8·13	7·53	5·69
Same from and at 212°	12·95	9·93	9·19	6·98
Actual evaporation from temperature of feed at temperature of steam per pound of coal	9·69	7·96	7·23	5·30
Same from and at 212°	11·90	9·72	8·84	6·51

The Thornycroft boiler experimented upon was one of those

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on the United States torpedo-boat "Cushing" built by Herreshoff; the stokers were ordinary navy firemen with little or no previous experience in the use of forced draught.

S. W. B.

Experiments on a Pair of Compound Steam Pumping-Engines at the Copenhagen Waterworks.—By F. OLLGAARD.[1]

At the Copenhagen Waterworks there are a considerable number of compound condensing pumping-engines of the beam type. The following experiments were made on a pair of engines of this type, coupled together on the same crank-shaft, and working four water-pumps, two from each beam. Each of them consists of high and low-pressure cylinders, the walls of which are jacketed with steam, but not the top covers. The dimensions of the engine are as follows:—

	Diameters.	Strokes.	
	Inches.	Feet.	Inches.
High-pressure cylinder	19	3	8·6
Low-pressure ,, ...	31	5	6
Main water-pumps	20	4	7·3

Two Cornish boilers furnished the steam used during the trials, which was supposed to contain 5 per cent. of priming water; the feed-water was measured into these boilers by a Kennedy water-meter. The water-pumps gave an efficiency of 98 per cent. of their contents.

The subjoined Table gives details of two sets of experiments, one with steam in the jackets, and one without. In those made without steam in the jackets it was not possible to run the engines faster. The jacket-water was carefully measured. When the jackets were on, the pressure in the jacket of the high-pressure cylinder was 40 lbs., in that of the low-pressure cylinder 37 lbs. For each lb. of steam condensed in the jackets, about 5 lbs. of steam were economized in the cylinders. It will be seen that there is a considerable gain in economy due to the jackets. The quantity of steam condensed in the high-pressure cylinder during admission was calculated at 28 per cent. of the total. The total expansion in both cylinders was about 10. It was reckoned that about 5 per cent. of the total heat was withdrawn from the walls of the cylinder, and carried off to waste into the condenser. The Table gives the chief points of interest in these experiments.

The Author is of opinion that it is important to jacket not only the high-, but the low-pressure cylinder with boiler-steam. He considers that these experiments prove the powerful influence

[1] The Danish original is in the library Inst. C.E.

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exercised by the metal walls of the cylinder, as already strenuously maintained by Hirn, whose theories and experiments here receive full confirmation. The action of the jackets he summarizes as follows: When the jacket does not work, the walls withdraw heat from the steam during expansion in the low-pressure cylinder; when the jackets are used, they impart it. The heat thus taken away from the steam is wasted during the exhaust stroke. The quantity of heat which passes from the jacket into the steam is small, but it exerts a very favourable influence owing to the fact that the walls, which act as a reservoir to store up and impart this heat, yield it to the steam at the right time, that is, during expansion. If no jackets are used the heat given up by the walls to the steam escapes to waste into the condenser. The temperature of the steam-jacket should therefore be maintained as high as possible.

TABLE OF EXPERIMENTAL RESULTS WITH AND WITHOUT STEAM IN JACKETS.

—	*With* Steam in Jackets.	*Without* Steam in Jackets.
Number of revolutions per minute	24	19
Mean boiler-pressure . . . . . lbs.	53	54·3
Mean temperature of feed-water	72° Fahr.	74° Fahr.
Consumption of dry steam per I.HP. per hour of water raised (jackets included) . . . lbs.	22·7	28·5
Lbs. of steam (with 5 per cent. water) per lb. of Newcastle coal . . . . . lbs.	7·57	7·48
Consumption of coal per I.HP. per hour of water raised . . . . . lbs.	6·3	8·0
I.HP. for each engine	81·1	65·7
Efficiency of engine (proportion between work done in water raised and indicated work) per cent.	85·22	83·45
Consumption of dry steam per I.HP. per hour (jackets included) . . . . . lbs.	19·3	23·8
Work due to the high-pressure cylinder in percentage of total	52½	60
Work due to the low-pressure cylinder in percentage of total	47½	40
Proportion of consumption of steam in the jackets to total . . . . . per cent.	6·25	..
Condensation of steam in the cylinder during admission . . . . . per cent.	28	40·4

In the original Paper an outline drawing of the engine, and copies of the indicator diagrams are given.

B. D.

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Graphic Method for Determining and Counterbalancing the Centrifugal Action of the Connecting-Rod.

By Passed Assistant Engineer A. B. CANAGA, U.S. Navy.

(Journal of the American Society of Naval Engineers, 1890, p. 433.)

The Author finds graphically the path of the centre of gravity of the connecting-rod, and its velocity at all parts of the path. The tendency of the rod to fly off at a tangent to its path is ever changing in amount, since the radius of curvature of the orbit and the velocity of motion along it are not constant.

Having found the mean radius of curvature, and the mean velocity of the centre of gravity, a diagram is constructed from which the weight of the counter-balance necessary to counteract the part of the centrifugal action of the connecting-rod which comes upon the crank-pin, can be determined.

Diagrams so made for an engine 6 inches in diameter, and 12 inches stroke, show that two-thirds of the weight of the rod acting on the crank-pin is to be balanced by a counter-weight, and the Author thinks that this will generally be found to be more nearly what is required than half the weight of rod, as recommended by some text-books.

S W. B

The Effective Area of Screws. By D. S. JACOBUS.

(Transactions of the American Society of Mechanical Engineers, 1890, p. 1028.)

Experiments made for the purpose of determining the effective areas of screws are described, and the results are said to confirm the statement in Rankine's "Shipbuilding," p. 89, that, "The effective area is the sectional area of the stream of water laid hold of by the propeller, and is generally if not always greater than the actual area in a ratio which, in good ordinary examples is 1·2 or thereabouts, and is sometimes as high as 1·4."

The ratio of the effective- to the actual disk-area of the screws experimented upon was found to be as follows:—

Tug-boat with ordinary true-pitch screw	1·42
„ „ screw having blades projecting backwards . .	0·57
Ferry-boat "Bergen" with ordinary true-pitch screw at speed of 12·09 miles per hour .	1·53
„ „ 13·4 „ „ .	1·48
Steamer "Homer Ramsdell" with ordinary true-pitch screw .	1·20

The low ratio in the case of the screw with blades thrown backwards is considered to be partly due to the fact that the blades

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were exceptionally thick, and 25 per cent. less in area than those of the screw it replaced.

The dimensions of the screws and data from which the above results are derived are:—

	Bergen.		Tug-boat.		Homer Ramsdell.
			Ordinary screw.	Special screw.	
Diameter of screw in feet	8		8·5	8·5	11·1
Pitch	8·9		12·0	14·0	15·8
Velocity of the boat through the water in statute miles per hour	12·09	13·40	11·77	11·32	16·02
Velocity of slip in statute miles per hour	2·18	2·88	1·73	4·5	2·00
Total indicated horse-power	435·4	684·7	342·6	329·5	1063
Estimated effective horse-power	267·1	420·1	210·2	202·1	652

The effective horse-power is taken as equal to 0·613 I.HP.

S. W. B.

A Pneumatic Accumulator for Hydraulic Machinery.

(Stahl und Eisen, vol. xi. 1891, p. 132.)

This arrangement, invented by Messrs. Prött and Seelhoff, in which the ordinary dead weight loading of the accumulator plunger is replaced by an air-buffer or compressor, is intended to prevent the danger due to the shock, at the change of stroke of heavily loaded accumulators when working at high speeds, and also to do away with the necessity of air-vessels on the pressure-mains, in which case the drawing over of air with the driving water is prevented, and a high hydraulic pressure may be produced by a much lower one of air.

As represented in the figures accompanying the description, the accumulator consists essentially of an air-cylinder and plunger placed above a water-cylinder and plunger, which are firmly connected by a framing of three vertical columns. The area of the upper plunger is ten times that of the lower one, so that when there is a pressure of 50 atmospheres in the air-vessel with the plunger at the bottom of the stroke, the pressure in the hydraulic cylinder will be 500 atmospheres when the plunger is lifted by water from the driving pumps. This pressure will of course go on increasing from the diminution of the space for the enclosed air as the piston rises, and conversely the pressure will diminish as the plunger falls, and water is drawn from the main by the machines at work. When this variation of pressure is not desired it may in some degree be prevented by making the body of the plunger hollow,

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and using it as a reservoir, or the working cylinder may be connected with a series of air-reservoirs by a pipe passing through the top cover. In an accumulator built for the Bochum Steel Works six of these reservoirs, 28 inches in diameter and 13 feet high, are used, the air-plunger being 30 inches in diameter. These were calculated to give a difference of about 10 per cent. between the beginning and end of the stroke, but in reality the inequality is considerably less, and in very rapid work the pressure at the end of the stroke is even a little in excess of that at the beginning, a result due to the work due to the mass of the plunger. Fewer reservoirs will therefore suffice, and four are now considered to be a more convenient number. In some instances, however, a comparatively rapid rise or fall in working pressure may be desirable, and in such cases the air-vessels may be dispensed with, or a valve may be placed on the communicating pipe which opens when the pressures exceed the required maximum, and closes automatically when the plunger is at the top of the stroke. An arrangement whereby the end pressure is about half that at the beginning of the stroke is found to be a most convenient one.

The air in the cylinder being a constant quantity, moving only between it and the reservoirs, does not require renewal except in case of leakage through the packed joints of the plunger. This is prevented by keeping a layer of fluid, preferably oil, in the bottom of the cylinder which prevents the air from coming in contact with the packing. A further source of leakage, namely, though the body of the cast steel plunger is similarly prevented by a watertight wrought-iron lining, enclosing a small annular space which is filled up by the oil, and so keeps the air out of contact with the steel casting, which, however good it may be will always be somewhat permeable when pressures of 50 atmospheres and upwards are used. For very high pressures the wrought-iron air-cylinder may be protected by a similar oil casing against leakage, or fluid carbonic acid may be used instead of air. In the latter case glycerine must be substituted for oil as a hydraulic packing.

For cranes and other machines, where a comparatively low working pressure is sufficient, both air- and water-plungers may be made of the same diameter, so that no increase of pressure is obtained and the construction is somewhat simplified.

The largest accumulator of this kind constructed up to the present time, was started in July 1890 at the Bochum Steel Works, where it replaced one with a dead-weight load. The working pressure is 500 atmospheres. A similar one has since been constructed for the same company's branch establishment at Savona in Italy. A smaller one has also been at work for about a year and a half at the Wissem Steel Works, and two others of the kind represented in the accompanying plate are in construction, the larger one being intended to work a forging press, and the smaller one a lifting plant.

H. B.

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On the Effect of Preservative Agents on Mine-Timber.

(Comptes-Rendus Mensuels de la Société de l'Industrie minerale, November, 1890, p. 223.)

At Saint-Eloy in Auvergne, experiments on the effect of antiseptic agents on the duration of timber underground, have been carried on since 1879, upon the following description of timber:—

1. Oak from the	Allier	35 years old.
2. „ „	Nièvre	27 „
3. Fir „	Allier	22 „
4. Pine „	„	20 „
5. Birch „	„	5½ inches diameter.
6. Beech „	„	„ „
7. Poplar „	„	„ „

Method of treatment.—A stem of each description of wood was sawn into fifty-two disks, each ¼-inch thick, the first and last of which were preserved in their natural condition above ground in the open air, but protected from damp, the remaining fifty were placed in a kind of cage in a damp level underground where the prevailing temperature was about 75° Fahrenheit. Two disks in each ten were left unprotected, while the remainder were subjected to treatment by the following substances:—

1. Sulphate of iron.
2. Sulphate of copper.
3. Chloride of zinc.

The strength of the solutions varied from 100 to 450 grams of the salt to 1 litre of water, and the period of immersion from one hour to four days.

4. Creasote, of the impure commercial kind immersed for similar periods.
5. Painted with three coats of the following oil colours: Pure white lead, white lead and yellow ochre, white lead and emerald green, red lead, white lead and lamp black, white lead and prussian blue.
6. Tar mineral and vegetable, immersion for five minutes.

After preparation, the samples were kept in the office at the surface for fifty days before exposing them underground, and they were subsequently examined at five different periods—namely, six months, one and a half year, two and a half years, three and a half years, and eight and a half years, the amount of alteration being laid down on a diagram which accompanies the Paper (Plate XXXIV.) From this it appears that the unprotected specimens were almost all destroyed in a comparatively short time—two and a half years to three and a half years—the observed order of durability being as follows:—

No. 1. Beech.	No. 5. Birch.
„ 2. Oak No. 1.	„ 6. Fir.
„ 3. Poplar.	„ 7. Pine.
„ 4. Oak No. 2.	

The preservative effects of the different substances employed is given in the following table, which represents the increase in the duration of the protected specimens in terms of that of the unprotected ones, the latter being taken as unity.

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—	Oak. No. 1.	Oak. No. 2.	Fir.	Pine.	Beech.	Birch.	Poplar.
Tar	28·7	24·6	263·5	87·5	105·4	26·2	150·5
Chloride of zinc .	10·5	9·2	50·0	26·3	18·6	52·5	34·7
Oil Paint . . .	6·1	10·2	31·7	54·5	25·0	12·1	2·5
Sulphate of copper	42·1	26·4	12·0	8·0	1·8	2·5	15·5
Sulphate of iron .	18·0	12·5	12·1	4·2	4·7	3·5	2·9
Creasote . . .	1·7	0·9	2·5	4·4	0·6	3·3	1·3

H. B.

The Darjiling Coal-field between the Lisu and Ramthi Rivers.

By P. N. Bose, B.Sc.

(Records of the Geological Survey of India, vol. xxiii. 1890, p. 237.)

The Author describes, with the aid of a map, the economic geology of the Darjiling coal field. Though observed by Sir Joseph Hooker in 1849, this coal was neglected until 1873, when the completion of the Northern Bengal State Railway give it a new importance. In that year Mr. F. R. Mallet reported against the workability of the deposit. The district has now been re-examined by the Author, and the discovery of thick seams of coking coal appeared so promising that it was considered advisable to ascertain their extent by excavations. All the rocks in the district have been greatly disturbed, and the crushing effect is specially noticeable in the shales and coal. The Author describes the various coal seams, giving a tabular summary of the principal ones, twenty-five in number, not less than 5 feet in thickness, omitting those which have been too highly altered by contact with igneous rock to be of value. With regard to quality, the coal may be classed under three heads:—

A. Cakes strongly. Ash less than 16 per cent.
B. Cakes strongly. Ash between 16 and 22 per cent.
C. Does not cake. Ash between 22 and 33 per cent.

The average percentage of ash in coal of class A is 12·23, and that of fixed carbon 61·44. The Darjiling coal (average of eight assays of classes A and B) may be compared with the Raniganj coal (average of thirty-one assays) as follows:—

	Moisture and Volatile Matter.	Fixed Carbon.	Ash.
Darjiling	59·56	22·94	17·43
Raniganj	53·20	30·63	16·17

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The utilization of the Darjiling coal depending largely upon its coking properties, practical tests were made in three kilns erected for the purpose. The coke produced was of good quality, containing but 0·62 per cent. of sulphur. The fact that so many of the outcrops have yielded good coke is the most hopeful feature about this coal-field. With regard to the quantity of coal available the Author confines his calculations to the central portion of the explored area. In this area of 97 acres, there is 5,592,645 tons of good coal almost immediately available. In this calculation, all coal with more than 22 per cent. of ash is neglected, the limit of workable depth is taken at 1000 feet, and the Author restricts himself to seams he has actually traced. For the whole area explored, which measures about 1 square mile, a fair estimate of the amount available is 20,000,000 tons, or 30,000,000 tons of coal if class C is also taken into account.

At the present time the difficulties of transport are considerable. The coal-field is advantageously situated with reference to mineral resources; important deposits of iron ore, of copper ore, of arsenic, and of tufaceous limestone occurring in the vicinity. Labour is scarce, as the district is scantily populated, and if the coal were to be worked, Nepalese labourers would have to be obtained. The cost of extraction of the coal would be less than in the Raniganj and Giridih districts, as, owing to its crushed condition, the coal can easily be dug out with picks. Extensive timbering would, however, probably be required. On account of its high dip, the coal has been brought to the surface, and consequently it will not be necessary to sink shafts through unproductive rocks.

B. H. B.

The Coal Seam of the Dore Ravine, Hazara.

By C. S. Middlemiss, B.A.

(Records of the Geological Survey of India, 1890, p. 267.)

The Author gives two sections of this coal-seam, which has been erroneously described by the engineers in charge of the mines, as lying with the adjacent limestones in the form of an anticlinal arch cut through by river action. The order of the strata on the left side of the section is, however, not the same as on the right side. As a matter of fact, it is inverted. The difficulties implied by such a structure are fatal to the development of the coal-field. In working the coal on the north side of the river, the engineer must be prepared for the continuous increase in the dip of the bed, until within 300 feet from the surface it assumes an angle of 80°; whilst on the south side it will pass the vertical until it rests at 80°, dipping in the same direction as the coal on the north side. These circumstances will necessitate expensive working. The Author is, however, confident that large quantities of serviceable coal may be extracted from the outcrops.

B. H. B.

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Experiments with Boiler-Plate Materials made at the Royal Technical College, Berlin. By — RUDELOFF, Chief-Assistant.

(Mittheilungen aus den koeniglichen technischen Versuchsanstalten zu Berlin, 1890, p. 289, 5 tables, 2 plates.)

PART II.[1]

The specimens were cut from plates of welding iron, Thomas iron and Siemens-Martin iron, in the condition in which they were delivered, *i.e.*, unannealed and tested in a Werder machine with the following mean results :—

I.—WITH GRAIN.

Material.	Modulus of Elasticity.	Limit of Elasticity.	Breaking Stress.	Elongation on		Reduction of Area.
				3·93 Ins.	1·96 Ins.	
	Lbs. per Sq. In.	Tons per Sq. In.	Tons per Sq. In.	Per cent.	Per cent.	Per cent.
Welding-iron .	29,300,000	14·50	22·8	27·9	33·5	42·2
Thomas iron .	29,200,000	18·90	26·1	28·0	34·6	52·7
Siemens-Martin iron . . .	29,100,000	13·75	22·2	32·7	40·9	58·0
Siemens-Martin iron . . .	29,400,000	12·90	21·6	32·6	41·0	57·7

II.—ACROSS GRAIN.

Material.	Modulus of Elasticity.	Limit of Elasticity.	Breaking Stress.	Elongation on		Reduction of Area.
				3·93 Ins.	1·96 Ins.	
	Lbs. per Sq. In.	Tons per Sq. In.	Tons per Sq. In.	Per cent.	Per cent.	Per cent.
Welding-iron .	29,400,000	15·8	21·6	17·2	19·9	24·7
Thomas iron .	29,200,000	18·1	25·7	25·8	33·8	49·2
Siemens-Martin iron . . .	28,900,000	13·6	22·3	28·2	37·7	53·9
Siemens-Martin iron . . .	29,000,000	13·25	21·8	30·7	39·2	57·2

The chemical tests are given in full, but do not show the same uniformity as the mechanical tests.

[1] Minutes of Proceedings Inst. C.E., vol. cii. p. 75.

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The Author next carried out experiments to ascertain the effect of annealing and tempering the various materials with the following results.

The annealing makes very little difference, but the differences due to hardening are more noticeable. This difference, however, cannot be due to irregularity in hardening as the same effect is noticeable both with and across the grain. Comparing the means of the annealed specimens it is found that the breaking stress is lowered in pieces tested with the grain by 7 per cent. and across the grain by 5 per cent., while the extension was increased in both, but not uniformly.

Effect of hardening is most marked in the case of the Siemens-Martin iron, where the breaking stress is increased by 71 per cent. and the extension decreased by 55 per cent. For the Thomas iron the values are 54 per cent. and 45 per cent. respectively, and for the welding iron 34 per cent. and 45 per cent.

The fractures are minutely described and well illustrated by photographs.

In the punching tests in the annealed, hardened, red-hot and blue-hot conditions the welding-iron is less tough than the Thomas iron. All tests showed the injurious effect of working at a blue heat and hardening. In annealed and red-hot conditions all the specimens were bent double without fracture, whereas this was not the case with the blue-hot and hardened specimens.

The hot bending tests were carried out as follows: Specimens 1·57 inch and 2·36 inches broad 6 inches long were nicked in the centre with a chisel to a depth of about 0·07 inch, warmed over a charcoal fire and put into a lead bath. Right temperature was ascertained by the colour of the specimen, and then specimens were broken with a sledge-hammer as quickly as possible, and arranged in six groups, according to the fractures, without reference to the test numbers. The angles at fractures were not taken, but the Thomas iron bent very considerably less than the Siemens-Martin iron.

The cold bending tests were carried out by nicking one side with a chisel to the depth of about 0·07 inch, and then bending the specimens in a press until fracture occurred, in order to show the nature of the material by the fracture. Twenty-four specimens were broken with and across the grain, and arranged in eleven groups according to the fractures without reference to the test numbers. Photographs of fractures are appended to the Paper. The Thomas iron shows by a long way the smallest angle before fracture. In the red-hot tests there is a considerable falling off in the angle in the case of the Siemens-Martin iron, *i.e.*, from 117° to 72° with the grain, and from 127° to 80° across the grain.

The Author then sums up in the following general conclusions:—

(1) In spite of the small percentage of phosphorus in the Siemens-Martin iron, the breaking stress was the same for annealed and unannealed conditions, whilst the effect in materials rich in carbon was more marked. According to the punching tests the

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materials with high percentage of carbon and low percentage of phosphorus seem to be the toughest.

(2) The Thomas iron with approximately the same chemical composition as the Siemens-Martin iron, both being rich in carbon, shows in the annealed and unannealed condition a higher breaking stress and lower extension.

After hardening the effect on the breaking stress is the same for all materials.

(3) The effect of hardening according to the tension tests is least noticeable in the Thomas iron, and according to the punching tests it is more marked in the Thomas iron than in the Siemens-Martin iron.

(4) According to the hammer tests the working at a blue-heat has an injurious effect on all the materials, and according to the bending tests the Thomas iron is most influenced.

(5) From the above it appears that the Thomas iron ought not to be prohibited, as is the case, for use in boiler construction.

L. S. R.

Experiments on the Effect of Pickling and Rusting on the Strength of Iron. By A. Ledebur.

(Mittheilungen aus den Koeniglichen technischen Versuchsanstalten zu Berlin, 1890. Supplement I.)

These experiments have been undertaken in order to obtain further information concerning the brittleness imparted to iron by the action of acid in pickling and by atmospheric rusting, which had been previously announced by the Author and other investigators, and to determine whether dangerous deterioration was likely to ensue from such causes. The former experiments having mostly been made with wires it was considered most desirable to extend them to objects of larger section, such as rails, joists, and bars. That has accordingly been done with the following articles:—

1. Steel rails, the Prussian state line section from Krupp's.
2. Wrought-iron joists, $9\frac{1}{2} \times 3\frac{1}{2}$ inches, from Koenigshutte.
3. Wrought-iron round bars, 0·8 inch diameter, from Lauchhammer.
4. Steel round bars, 0·8 inch diameter, from Peine.

5*a*. Wrought-iron wire, 2·2 millimetres diameter, from Felten and Guilleaume.

5*b*. Steel wire, 2·2 millimetres diameter, from Felten and Guilleaume.

These were treated in the following manner:—

I. In the condition as delivered.
II. After exposure for the purpose of rusting.

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III. Zincked (galvanized) and tested at once.
IV. Galvanized and exposed for a time.
V. Pickled in acid and immediately tested.
VI. Pickled and kept for a time in a dry place.

The pickling was done with sulphuric acid diluted with water in the proportion of 1 : 100, and the metal was protected from direct attack by covering one end with melted zinc, the time of immersion being seventeen hours. In a few instances, in order to render the effect more visible, stronger acid 1 : 50 and a period of forty-one hours was used. The alteration due to rusting by two months' exposure was, except in a few instances, scarcely appreciable, and a continuance of the experiments for a longer period was likely to have led to a partial destruction of the material and to erroneous conclusions from the result.

The samples were tested transversely in tension and compression, and under a falling weight, three experiments being made on the same sample for each of the six conditions, and the tabulated results given at length fill twenty-four pages. The general conclusions given in the introductory report are as follows :—

1. *Bending tests with wrought-iron joists.*—The elastic properties, amount of bending, and limit of proportionality are substantially the same for all the conditions tested, the flexure for given loads being almost identical when the average results are compared. The maximum loads carried show differences, being highest in the natural conditions and lowest when freshly pickled. Rusting also produces a diminution in strength, which is more apparent in the galvanized than the ungalvanized pieces. In the few instances where the specimens were broken by the tests, the diminution in strength is very decided in the pickled and perceptible in the rusted specimens. The figures for these are :—

Conditions.	I.	II.	IV.	V.	VI.
	Tons.	Tons.	Tons.	Tons.	Tons.
Breaking-strain	35	33·9	32·7	29·6	30

Bending-tests with steel rails.—The length between the supports was 1 metre; none of the specimens were broken. The average values from the results show that neither elastic nor ultimate strength are affected by any of the methods of treatment; the rusted specimens, whether galvanized or not, giving rather the highest figures. This may possibly be due to the chemical composition, which is as follows :—

Carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.	Copper.
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
0·25	0·21	0·47	0·10	0·06	0·08

A very marked difference was observed in the behaviour of the pickled specimens, those of wrought-iron, even after immersion for several hours in lime-water to remove all traces of free acid, gave

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off a strong smelling gas, probably a hydro-carbon compound, for several hours, while those of steel were perfectly odourless. This seems to show that acid sets up chemical changes in wrought-iron that it is not competent to produce in steel.

Tensile-tests with round steel and iron bars.—Neither ultimate nor elastic limit was sensibly altered by any method of treatment under the conditions of the experiments; but it is considered that differences might have been produced had the action been longer continued.

Tensile- and bending-tests on wires.—The strength of ungalvanized wire, both of iron and steel, is diminished by rusting. Galvanizing diminishes the absolute tenacity, but increases the proportion of elongation. The elastic limit and ultimate tensile strength observed for the different conditions were:—

—	I.	II.	III.	IV.	V.	VI.
Iron.						
Elastic (kilograms per millimetre) .	51·9	42·5	45·1	50·2	..	..
Ultimate (kilograms per millimetre) .	55·0	50·6	52·4	52·6	55·8	57·1
Elongation (per cent.)	4	3·3	15·1	13·5	5·5	5·0
Bends	12	10	11	9	7	11
Steel.						
Elastic	109·1	107·7	103·9	103·9	109·1	114·3
Ultimate	121·1	117·7	116·3	117·3	121·7	121·0
Elongation . . .	8·7	7·5	18·0	16·5	9·0	9·0
Bends	13	9	12	12	11	12

These results indicate that the diminution of flexibility in pickled and rusted wire is less than that obtained in previous experiments. This, however, is mainly due to the circumstances that in the latter the acid used was stronger, or the action if weak was allowed to continue for a much longer time.

Compression-tests with iron and steel.—These were applied to test-pieces 30 and 50 millimetres high. No very sensible differences due to treatment were observed, the diminution of height for successive equal increments of weight being about the same. The ultimate strength was not determined owing to the bending of the test-pieces and the limit of power in the machine, which was 100 tons. Under the impact of a weight, viz., 56·7 kilograms falling 1 metre, freshly pickled wrought-iron was bent about 10 per cent. more by the same number of blows than when in the state received from the works. This effect was obtained with the steel specimens. A supplementary series of bending and falling weight-tests was made upon bars about 48 millimetres square of steel of the following composition:—

Carbon. Per cent.	Silicon. Per cent.	Manganese. Per cent.	Phosphorus. Per cent.	Sulphur. Per cent.
0·51	0·75	1·42	0·09	0·094

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both in the natural condition and after pickling with acid 1 : 50 for forty-one hours. There was no difference in the elastic limits under steady loading, but by impact the pickled specimens bent more readily after the fourth blow than the unprepared ones. The breaking-strain under either condition was sensibly diminished from 142·7 kilograms to 126·8 kilograms under steady load, and from 1643·5 net kilograms to 895·6 net kilograms total energy of blow to produce fracture by the falling weight. The diminution is not, however, as large as that observed by previous experiments, where the breaking strain was reduced from 169·5 kilograms to 102·5 kilograms by pickling. The latter results were, however, obtained with bars of smaller section—22 millimetres as against 48, and remained in the acid for nine days. The steel treated on the present occasion was also exceptionally rich in silicon, which no doubt added to its resisting power.

As regards chemical composition the susceptibility of iron to become brittle by pickling and rusting is least in cast-iron and silicon steel, and highest in wrought-iron, and, according to Bädecker, in high-carbon steel. Combined carbon appears to increase the action and silicon to diminish it. The influence of manganese in either direction has not as yet been determined.

H. B.

Test of Ores from Schemnitz and Altai at the Alsó Kapnikbánya Smelting-Works. By Karl Laske.

(Berg- und Huettenmaennische Zeitung, 1891, p. 33.)

To supplement the description of the Alsó Kapnik smelting-works, published 1889 and 1890,[1] the Author now gives the results of two trial lots of ore treated by the Bittansky process.

In consequence of the previous Papers on this subject containing such authentic proofs of the economy of this method numerous applications from home and foreign mines (including distant countries such as Transvaal and Australia) have been received for treatment of their ores. This has been permitted, and representatives are invited to study the operations. The results given below have been verified by actual sales of the metals extracted to the mint and other quarters. The following gentlemen were present during the whole of the process: Mr. V. Laske, Mr. E. von Bittansky, Mr. A. Maly, Mr. N. von Koksharof, and the manager and officials of the works.

I. Test of Ores from Altai.

The ores consist of iron and copper pyrites, zincblende, galena, quartz, and gauque, carrying small quantities of gold and silver.

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[1] Berg- und Huettenmaennische Zeitung, 1889, pp. 413, and 1890, pp. 203.

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The proportion of zincblende varies from 45·28 per cent., and in consequence smelting would not be an economical treatment for this ore, even if fuel were abundant and cheap in the neighbourhood of the mines, which it is not. The Bittansky process is therefore very suitable, with the exception perhaps that the zinc is not recovered, a previous hand-picking or dressing is advised to avoid this loss. The ore arrived in three parcels; the combined weight was 4 tons 1 cwt. 2 qrs. 26 lbs., consisting of 60 per cent. leaching material (metallic sulphides), and 39 per cent. of sulphide of zinc, and containing 1·89 lbs. of copper, 20·3 lbs. of lead 3 dwts. 7 grs. of silver bullion, and 1 dwt. 7 grs. of gold.

After mixing the ore was subjected to a preliminary roasting in a reverberatory furnace, as it contained too great a quantity of sulphides to enable a direct chlorinizing roasting in the Bode furnace (50 per cent. being the limit this furnace can cope with efficiently). This preliminary roasting completed, the patent process was gone through in the usual manner, with the result that 92·4 per cent. of the silver, 89 per cent. of the gold, 36 per cent. of the lead, and 100 per cent. of the copper contained in the ore was extracted.

The cost for roasting and leaching was 1*s.* 7*d.*, that of smelting and refining the products 11·6*d.* per cwt.; total cost 2*s.* 6·6*d.* per cwt. In the year 1889 the cost of treatment of this class of ore was 3*s.* 4*d.* per cwt.

II. Testing of Schemnitz Ores.

The ores were delivered in three parcels, viz :—

I. Silver slimes containing 21 per cent. of leaching material, 4·9 per cent. of sulphide of zinc, and 6 dwts. 12 grs. of silver bullion, and 1 dwt. of gold to the cwt. of ore.

II. Silver slimes containing 30 per cent. of leaching material, 5·1 per cent. of sulphide of zinc, and 4 dwts. of silver bullion, and 1 dwt. 8 grs. of gold to the cwt. of ore.

III. Silver ores containing no leaching material, 4·9 per cent. sulphide of zinc, 6 dwts. 8 grs. of silver bullion, and 6·8 grs. of gold to the cwt. of ore.

The whole consignment weighed 88 tons 14 cwts., and contained, on the average, 11 per cent. of leaching material, 4·9 per cent. sulphide of zinc, and 6 dwts. 8 grs. of silver bullion, and 12½ grs. of gold to the cwt. of ore.

In order to ensure the most perfect method for conducting the chlorinizing roasting, preliminary tests were made on small parcels of the ore, both in the Bode furnace and reverberatory furnace, the best and cheapest result was obtained in the reverberatory furnace with 9 per cent. of leaching material. The bulk test was therefore accordingly conducted with the excellent result, that the total loss of silver amounted to only 1·85 per cent., and that of gold to 24·17 per cent., while 125 lbs. of copper and 720 lbs. of lead were also extracted, which metals had not been taken into

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account in the valuation of the ore on account of the insignificant quantity in which they existed. The cost (not counting the expenses of management) were for roasting and chlorinizing 11·88*d.*, for leaching 6·96*d.*, and for smelting and refining the products 9·36*d.* per cwt., or a total cost of 2*s.* 4·2*d.* per cwt.; to this must be added the value of the copper and lead, giving an equivalent of an additional 2·2*d.* per cwt.

The cost of treatment of these ores at Schemnitz is 6*s.* 3*d.* per cwt. There is, therefore, 2*s.* 4·2*d.* − 2·2*d.* + 1*s.* 2*d.* for management = 3*s.* 4*d.* against 6*s.* 3*d.*, or a saving of 2*s.* 11*d.* per cwt.

H. L. L.

The New Chimney-Stack at the Halsbrueckner Works, Freiberg.

By O. Hueppner.

(Oesterreichische Zeitschrift fuer Berg- und Huettenwesen, vol. xxxix., 1891, p. 96.)[1]

The new chimney at the Halsbrueckner smelting works, which was completed at the end of October 1889, and brought into use about six months later, is intended to carry away the deleterious gases from the calcining and blast furnaces and discharge them into the atmosphere at such a height above the ground to prevent any nuisance to the surrounding habitations, for which purpose a height of about 100 metres (324 feet) above the highest ground in the neighbourhood was determined to be sufficient. The selected site is on a hill overlooking the Mulde valley about 12 metres before the summit, and distant about 450 metres from the works, with which it is connected by a flue following the rise of the ground. The total height is 140 metres, the top being 200 metres above the level of the lower part of the works. The leading dimensions of the chimney, which is of circular section, are:—

Total height	140 metres
Height of base	9 „
Diameter of stack at top (inside) . .	2·5 „
„ „ at base „ . . .	5·25 „
Thickness of stack-wall at top . . .	0·25 „
„ „ „ at base. . .	1·50 „
Average thickness throughout . . .	0·837 „
Bearing surface at base	31·8 square metres
Outside batter of stack	1 in 50
Bottom breadth of rectangular base .	10 metres
„ „ foundation pillar .	12 „

In the determination of the thickness of the walling the following data were assumed:—Wind pressure, 150 kilograms per

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[1] This is an abstract of a longer illustrated description in "Jahrbuch fuer das Berg- und Huettenwesen im Koenigreiche Sachsen, 1890."

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square metre effective upon one half of the complete surface projection; coefficient of stability, 4·3; and weight of the finished brickwork 2,000 kilograms per cubic metre. The corresponding pressures under the maximum wind effect are:—

	Kilos. per Square Centimetre.
On the stack and base	17
„ foundation	9
„ ground, solid rock	5·1

While the maximum pressures due to the load at rest are:—

	Kilos. per Square Centimetre.
On the bottom of the stack	11·3
„ „ base	6
„ „ ground	3·8

In order to keep the maximum loading within the limit adopted, 17 kilograms per square centimetre, it has been necessary to make the lower part of the stack up to within 94·3 metres of the top thicker than is required on the mere consideration of stability alone.

The total height of the stack is 131 metres, which is divided into twenty-six annular sections, each diminishing in thickness upwards by 5 centimetres in each section. The sections are of varying height, the thickness at the top of each one in ascending order from the base being as follows:—

Metres.	Metre.	Metres.	Metre.
At 3·1	1·50	At 68·9	0·85
„ 6·2	1·45	„ 81·5	0·80
„ 9·3	1·40	„ 89·8	0·75
„ 12·4	1·35	„ 94·1	0·70
„ 15·5	1·30	„ 98·4	0·65
„ 18·6	1·25	„ 102·7	0·60
„ 21·7	1·20	„ 106·7	0·55
„ 24·8	1·15	„ 110·7	0·50
„ 27·9	1·10	„ 114·7	0·45
„ 31·0	1·05	„ 118·7	0·40
„ 34·3	1·00	„ 122·7	0·35
„ 37·8	0·95	„ 126·7	0·30
„ 56·3	0·90	„ 131·0	0·25

The material used is a hard-burnt pressed brick from Ilse, near Sentenberg, having a mean specific gravity of 2·05, and a resistance to crushing of more than 400 kilograms per square centimetre, the absorptive capacity measured by the increase of weight by immersion in weak acid or water is from 4·5 to 4·8 per cent. The excellent character of this brick allowed the reduction of the upper section to the small dimension of 25 centimetres in accordance with the precedent of the Mechernich stack of 135 metres.

The standard composition adopted for the mortar was one part of cement, nine of Bohemian hydraulic lime, and twenty of

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Dresden building sand, all by volume. In the upper length of 90 metres the proportion of cement was doubled in order to hasten the work, and the last course at the top was increased to four parts. The entire outer surface of the stack was pointed with mortar made of equal parts of sand and cement.

In order to prevent the penetration of the brickwork by the chimney gases, the facing of the inside rings were tarred on one face by immersing them at one end for four hours in boiling tar, which was done at the works immediately after drawing them from the kiln. The inside pointing was done with a mixture of four parts of Dresden sand to one of infusorial earth boiled in tar and worked on hot.

The brickwork is further protected by iron rings of 70 by 12 millimetres section, put together in four segments whose distance from each other is taken at two-thirds of the diameter of the stack at the corresponding level, and that which has the effect of bringing them closer together as the height increases. The cap of the chimney is of cast-iron U section built up in sixteen segments, which enclose the top of the stack. The butt edges of the segments are provided with projecting lugs, which support cast-iron cappings covering the joints. By this arrangement the iron cap is made entirely independent of the brickwork, and is free to expand and contract without reference to the latter. Climbing irons are provided both inside and outside. The inner ones are in double series opposite to each other, and were used for supporting the bearers of the lift pulleys during the building. The outside irons are supplemented by safety staples placed 54 centimetres apart, which not only serve for protection in climbing, but as a support for the back while resting. Two 10-millimetre copper lightning-conductors are carried down the outside, each having its own copper earth-plate of 2 square metres surface at a distance of 90 metres from the bottom of the chimney. One of them is buried in damp ground, while the other is placed in a cistern through which a current of water is constantly flowing. At the top both are connected by an iron ring to the cast-iron cap, and one of them is further in conductive connection with each of the iron outside rings of the stack.

The work was carried out by contract by Mr. H. R. Heincke, of Chemnitz, the first course of the foundation having been laid on the 28th September, 1888. The rock, a compact gneiss, was dressed up by hand and levelled by a bed of concrete 10 centimetres thick, upon which the brickwork was begun. The foundation pillar and half the height of the base block, 650 metres, were finished in fifty-two days, the drying of the brickwork being accelerated by artificial drainages. In the spring of 1889 the work was resumed in April, and on the 4th of May the building of the stack was begun without the use of external scaffolding, a steam-lift with a portable engine being used as the height increased. The number of bricklayers at work was at first eight, afterwards six, and finally four, as the section diminished. In fine weather the work

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was carried on at night with the aid of electric light, and in spite of several interruptions by rain and storms the work was finished by the placing of the cap on the 28th of October, 1890. In the construction, in addition to the iron armature, which weighs 15¼ tons, five hundred and forty truck-loads of 10 tons each of building materials were delivered. The total cost was about £6,500.

H. B.

A Method of treating Complex Silver Ores containing Zinc.

By W. West.

(Engineering and Mining Journal, New York, vol. li., 1891, p. 321.)

At Thomasville, in North Carolina, the Author, in 1889–90, treated several hundred tons of argentiferous lead ores containing blende and pyrites, by the following method:—

The ore was crushed, to pass a forty-mesh screen, and if containing more than 21 per cent. of zinc, pyrites was added to reduce it to that proportion. It was then roasted, and the sulphur gases, after being drawn through a coil of pipes cooled with water, were forced by a Root's blower through a charge of the roasted ore, placed in a tank with a false bottom, a jet of steam at low pressure being injected simultaneously with the sulphur dioxide gas. The result is the change of the zinc oxide to sulphite, and ultimately to sulphate, which may then be readily extracted by washing with water. It rarely happened that more than two-thirds of the zinc, 14 out of 21 per cent., was removed by the first washing, and a repetition of the operation was necessary by which the whole of the zinc oxidized in roasting was removed.

The roasting was done in a muffle-furnace of 5 tons capacity, and four tanks, 10 feet square and 40 inches deep, were required for the gassing process, which was continued for thirty-six to forty hours.

The extraction of the zinc sulphate was done in a second series of vats, as the action of the gas caused the charge to pack so closely that it was impossible to subject it to a second gassing until it had been opened out again. The residue of the extraction containing the lead and precious metals was dried upon a floor heated by the gases of the roasting furnace, and was then ready for the lead smelters.

The zinc in the sulphate solution was recovered by precipitating it as hydrated oxide with ammonia supplied in the form of gas from a still, and when washed, dried and heated, gave zinc oxide in a saleable form. The final solution was then returned to the still, and the ammonium sulphate was decomposed with caustic lime. The loss of ammonia was a little more than 3 per cent. of the weight of the zinc recovered.

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The average returns obtained from the process were the full assay value of the gold and silver, 80 per cent. of the lead, and 70 per cent. of the zinc as oxide.

H. B.

Zinc-Ore Mining in Sweden.

(Oesterreichische Zeitschrift fuer Berg- und Huettenwesen, vol. xxxix, 1891, p. 106.)

The position of Sweden as a zinc-producing country is mainly due to the work of the Vielle Montagne Company, who shortly before 1860 purchased the Ammeberg ore-deposits, and built large dressing-floors and a railway to navigable water for the export of the product. These mines are still the principal contributors to the total produce of the country—72 per cent. in 1889, the next place being held by the neighbouring Låggesta mines, which, after lying idle for several years, were reopened in 1887, and in 1889 produced nearly one-fifth of the quantity raised at Ammeberg. The yield for the three years, 1887 to 1889, inclusive, was as follows :—

	1887.	1888.	1889.
	Tons.	Tons.	Tons.
Åmmeberg .	41679·5	42195·4	43009·0
Låggesta . .	561·0	3966·6	7784·0
Langfallsgruben	1789·7	1058·2	2760·4
Dannemora. .	1102·3	1567·7	2116·0
Rylshytte . .	..	730·3	1865·3
Kafveltorp . .	776·7	444·6	824·5
Sundry mines .	332·1	9·1	1021·8
	46241·3	49971·9	59381·0

As regards the yield of the ore of the total output of 126,883 tons at Ammeberg during the years under review, 22,415 tons, or about 18 per cent., was lump blende, which required no dressing but only crushing and roasting. The remainder of the output, 82 per cent., or 102,922 tons, was mixed ore stuff, which by dressing gave 43,529 tons of smelting ore, or 1 ton of the latter to 2·37 tons of the former. In the same period 64,410 tons of ore were roasted, giving 59,504 tons of calcined ore for export. In the dressing-operations 5,533 tons of lead ore were saved as an accessory product, or about 4½ per cent. of the weight of the zinc-ore treated.

H. B.

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Stein's Concentrator. By C. Bloemeke.

(Berg- und Huettenmaennische Zeitung, 1891, p. 69.)

This is an invention of Mr. Stein, of Freiberg, and has been perfected and adapted to practical purposes by Mr. Bilharz.[1] It was first used at the new central dressing-works of the Himmelfahrt mines, near Freiberg. This machine differs from the older constructions described by Rittinger by its shaking revolving motion, and, unlike the newer American inventions, *i.e.*, Frue vanner, Triumph Concentrator, &c., is adapted to separate and deliver from four to five grades of concentrates, or different products.

The apparatus, of which the Author gives a drawing, consists of a wooden frame, in which rollers are fixed, over and through which an endless rubber belt revolves. This belt is not inclined longitudinally, as with the Frue vanners and kindred machines, but slopes towards the side; lengthways it is horizontal. It is fed from the top right-hand corner (the belt revolves from right to left), and discharges over the whole length of the lower edge or side. Adjusting-screws are fitted, to enable the belt being inclined to the angle most suited for the material it has to treat. To ensure an even surface, and to avoid adhesion of the rubber to the rollers, narrow troughs, continuously filled with water, are fitted under the belt, which form a cushion, over which it glides. To prevent the belt from running askew on the rollers, small wooden pivots are fixed to the underside, which correspond and fit into slots on the rollers. A percussion motion is effected by an eccentric, thrusting the frame, with belt, &c., forward, while a spring reacts backwards, knocking the apparatus against a buffer. The number of percussions per minute are one hundred and fifty. The speed at which the belt travels is about $2\frac{3}{4}$ inches a second.

The pulp, being fed on to the belt at the upper corner, moves forward with it. The effect of the percussion is to speedily separate the particles contained in the pulp, which adhere to the rubber coating and are carried towards a perforated jet-pipe, placed diagonally across the table, from the left-hand lower corner to the right-hand upper edge, where the feed is charged. The jets of water play on and towards the advancing particles, and wash them according to their specific gravity, over the lower edge of the inclined belt. A receiving launder, divided into compartments to suit the circumstances, is placed immediately under the discharging side of the table. For greater convenience and facility of adjustment, sheet-iron boxes can be substituted for the launder.

The diagonal position of the jet-pipe naturally causes a loss of working surface on the belt, but this has been found to be unavoidable.

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[1] Die Oesterreichische Zeitschrift, No. 19, 1890.

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The usual length of belting is 8 feet $2\frac{1}{2} \times 2$ feet $5\frac{1}{2}$ wide. At Freiberg these machines yield the following different products:—

(1) Tailings.
(2) Iron pyrites and zincblende.
(3) Pure iron pyrites.
(4) Arsenical pyrites and galena.
(5) Pure galena.

The discharge-surface of the different products on the lower side of the belt varies, of course, with the class of material treated; the average has been found to be as under:—

(1) Tailings, 2 feet $7\frac{1}{2}$ inches.
(2) First intermediate product, 1 foot $7\frac{3}{4}$ inches
(3) Second „ „ 1 „ $7\frac{3}{4}$ „
(4) Pure galena . . 2 „ $1\frac{3}{4}$ „
} 8 feet $2\frac{1}{2}$ inches.

Among the principal places where these machines are in use, the Author mentions Ramsbeck, in Westphalia; Werlau, on the Rhein; Laurium, in Greece, and Muhlenbach, by Ehrenbreitstein.

The end, or final product of the Stein Concentrator, is in every case pure; the intermediate ones, which generally consist of galena and zincblende, are re-treated on the same machines, when a perfect separation of the two minerals is effected.

The Author says this concentrator is one of the most perfect in existence for treating high-grade slimes. From a qualitative point of view, it does better work than any other known machine; its capacity, however, is not so great as the Linkenbach, or the revolving buddle. The Rittinger table is inferior to it, both in efficiency and capacity. At Freiberg the excess of work of this machine over the Rittinger table has been found to be 4·4 lbs. per minute.

From a labour-saving point of view it is economical, one man being able to attend to three or four machines with ease.

Experiments on galena and zincblende slimes, with Frue vanners and kindred machines, have not given satisfactory results, and the Author considers the Stein Concentrator superior to these, apart from the facts that its first cost is less, it requires less power, it is more economical to keep in repair, and requires less foundation.

One disadvantage is that the belt is liable to pucker, if not of sufficient thickness; the Author recommends $\frac{1}{8}$ inch as the correct thickness.

For the treatment of large bodies of low-grade ores, the Author advises a combination of two or three of these machines with a Linkenbach buddle, which latter will partially dress the pulp and pass the intermediate products on to Stein's Concentrator for final separation.

H. L. L.

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A New Gold-Coloured Alloy. By T. HELD.

(Dingler's Polytechnische Journal, vol. 279, 1891, p. 119.)

The Author has invented an alloy of copper and antimony in the proportion of 100 to 6 which is made by melting the copper, and when at the right heat adding the antimony; and when both are melted and intimately mixed, fluxing the mass in the crucible, with an addition of wood-ashes, magnesium and carbonate of lime, which has the effect of removing porosity and increasing the density of the metal when cast. The alloy can be rolled, forged, and soldered in the same manner as gold, which it very closely resembles when polished, the gold colour being unchanged, even after long exposure to ammonia and acid vapours in the atmosphere. It is also much stronger than gold. The cost of the alloy in the ingot is about 1*s.* per pound.

H. B.

The Influence of Hardening upon the Electrical Resistance of Steel. By H. LE CHATELIER.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxii., 1891, p. 40.)

Hardening of steel has been of course practised for ages, but the principles upon which the practice is based are still not well understood. The question is difficult, and the mere fact that the chemical composition, temperature, etc., of the material are known does not lead to an accurate perception of what occurs. For example, if a bar be cut into small portions, and these brought close together, the electrical conductivity and density are the same as in the original bar while the tenacity is zero. Without going to such an extreme case it may be said that all bodies are formed of aggregates of crystals, of which the form, size and polarity may vary infinitely. The internal changes appear in the grain of the fracture, and modify the properties of the material to a considerable extent.

The hardening of steel modifies both its chemical composition and its internal structure. These two results should be examined separately. Mr. Osmond used the variation in the condition of the contained carbon to designate the chemical state of the metal.

The Author believes it possible to arrive at more precise results by investigating the electrical resistance of the material.

Tests were made upon wires 0·0078 inch diameter, and 3·94 inches long. The following Table gives the resistance of the

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metal in ohms reduced to the standard size of 39·37 inches in length and 0·0039 inch diameter, as well as the percentage of contained carbon.

Ohms, resistance	0·190	0·250	0·27	0·22
Percentage of carbon . . .	0·085	0·485	0·67	0·83

The influence of the initial temperature of heating is important. The increase in the electrical resistance of the hardened metal only begins at a certain well-defined temperature; it is sudden, and does not increase with a further rise of temperature.

The exact point at which this occurs varies slightly, according to whether the temperature is rising or falling, from the known fact of the inertia of the molecular changes, such as overheating, over-melting, over-saturation. The following Table gives the mean of the temperatures of the hardening with a rise and with a fall of temperature, as well as the resistance expressed as a function of its initial value previous to hardening:

Temperature, Fahrenheit .	1,282°	1,373°	1,337°	1,355°
Resistance in ohms . . .	1·13	1·18	1·55	1·60

In these tests uncertainty as to strength occurred at the same time as the increase of the electrical resistance. The temperature of hardening of steel is thus that of the transformation of carbon (1,346°). These results confirm the theories of hardening obtained by Mr. Osmond upon this most important point, that the positive hardening, that is, the hardening accompanied with weakness of the material, has the effect of preserving, at the ordinary temperature, the molecular condition of carburetted iron which is only normally stable above 1,346°. On the contrary, these results weaken his theories upon the secondary point that hardening would retain part of the iron in the β state, that is, in the molecular state stable above 1,560°. If this were so, hardening should give different results, according as slaking took place above or below 1,560°, which is not the case. Besides this, the magnetic conditions should be changed by hardening; but ferro-nickel and manganese steel, in which the existence of iron in the β state seems certain, are not at all magnetic when cold, while iron and ordinary steel are so when heated above 1,560°.

These tests prove that in mild steels hardening, although not producing weakness, yet hinders the transformation of carbon quite as completely as in hard steels.

Annealing Steel.—When steel is heated its electrical resistance decreases by a quantity which increases according as the temperature is higher, and the heating is more prolonged. There appears to be for each temperature a limit to this decrease which would be only attained after the lapse of an infinite time, but for all practical purposes the greater part of the annealing takes place in a very short time. The following Table gives the resistance of steel

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No. 3 slaked off in water at 50°, and then annealed for a minute at increasing temperatures.

Temperatures . .	50°	250°	400°	590°	725°	840°	1,020°
Resistances in ohms .	1·55	1·47	1·29	1·15	1·10	1·07	1·04

The Effect of Temperature of the Slaking-trough.—The results obtained in slaking steel in baths at an increasing temperature have been, so far as electrical resistance is concerned, similar to those obtained by slaking off at a low temperature, and then reheating to the temperature of the slaking-trough. In considering the change of resistance during the hardening, it must be remembered that the temperature of the specimen and of the fluid is quickly equalized with wires of 0·0078 inch diameter. Then the condition of the wire remains constant for a period varying from some seconds to several minutes, according to the temperature and to the quality of the steel, and the metal is completely hardened. Then the process of re-heating begins quickly and continues at a rate which falls rapidly. The phenomenon is similar to the freezing of water, the temperature of which has been lowered below the normal freezing point by a rapid cooling. The same retardation in the transformation is not noticeable in the ordinary method of annealing by re-heating.

The results collected in the following Table were obtained by slaking steel heated to a temperature between 1,272° and 1,652° in baths at variable temperatures, retaining it in the bath for one minute and then allowing it to cool down in the air.

	Ohms Resistance.			
Cold water, mercury, and a freezing mixture	1·13	1·18	1·55	1·60
Boiling water	1·06	1·09	{1·09 / 1·55}	1·09
Nitrates of the alkalis, at 480°	1·08	1·15	1·55	1·40
„ „ 660°	1·02	1·07	{1·02 / 1·55}	1·17
„ „ 840°	1·02	1·01	1·01	1·03

Steel No. 3 gave in certain cases discordant results from the fact of the retardation in the annealing referred to above, and which varied from one test to another. The effect of slaking in boiling water is almost nothing, cooling takes place so slowly as to allow of the production of recalescence.

This first series of tests demonstrates the fact that by measuring the electric resistance of the metal, the state of the contained carbon may be ascertained and also to some extent the part of it which is transformed in steel which has been hardened. This method will be used by the Author in further research into the mechanical properties of steel.

E. R. D.

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On the Electrical Resistance of Metals. By H. LE CHATELIER.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxi., 1890, p. 454.)

This is a sequel to the Author's Paper on the "Influence of hardening upon the electrical resistance of steel," and is an application of the same method to a new series of metals and alloys.

Those metals which show no molecular changes before fusing have electrical resistances which vary directly with the temperature plus a constant, as is illustrated by the following examples.

RESISTANCE IN OHMS OF WIRES 0·0039 INCH DIAMETER.

Pt	$0{\cdot}140 + 0{\cdot}000180\ (t + 32°)$
Pt + 10 per cent. Rh	$0{\cdot}335 + 0{\cdot}000195\ (t + 32°)$
Cu	$0{\cdot}032 + 0{\cdot}000055\ (t + 32°)$
Cu + 10 per cent. Sn	$0{\cdot}150 + 0{\cdot}000060\ (t + 32°)$
Cu + 20 per cent. Ni	$0{\cdot}420 + 0{\cdot}000060\ (t + 32°)$
Ag	$0{\cdot}023 + 0{\cdot}000058\ (t + 32°)$

where t stands for the temperature in degrees Fahrenheit.

It will be seen that copper, silver and their alloys, have a coefficient for temperature almost identical and approximately 0·000060; while the coefficient for platinum and its alloys is three times as great.

Silver has an interesting peculiarity, for when heated in oxygen its curve for electrical resistance remained quite straight, its mechanical properties were not changed, and its melting point was found to be 1,733°, which is almost identical with that of 1,750° given by Mr. Violle. When, on the other hand, it was heated in hydrogen all its properties were changed from the temperature of 1,200°, its resistance increased more rapidly than when in oxygen, and the metal after cooling showed great loss of strength; wires of 0·001 inch diameter could not be bent without breaking, and the melting point was lowered to 1,680°. The metal takes on a dull appearance similar to that of palladium obtained by deposition from its hydrate. These facts prove that silver at a red heat occludes hydrogen. The Author states that he believes that the quantity of hydrogen occluded is too small to form a definite chemical compound, and that the metal does not retain a measurable quantity of it after cooling.

A large number of the metals show like iron sudden molecular changes which occur at well-defined temperatures.

The electrical resistances then show at those temperatures sudden variations in their law of increase, but their absolute value does not change on passing a point where these changes occur, as is the case at the melting point. The Author then gives curves demonstrating these phenomena. The best result was obtained with an alloy of a composition, Cu 70, Ni 18, Fe 11. The temperatures

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at which molecular changes occur in some of the specimens are as follows :—

Zinc	680°
Brass, with 38 per cent. of zinc	1,330°
Alloy Cu, Fe, Ni	1,270°

The Author has found by direct experiment that in brass the molecular change is accompanied by a considerable absorption of latent heat. Some alloys show progressive molecular changes which call to mind those observable in the chemical equilibrium of saline solutions such as those of the salts of chromium and of chloride of copper, &c. The transformation is not instantaneous, but takes place as a rule within a limited range of temperature, as may be seen with aluminium bronze, containing a small percentage of silicon where the change takes place between 1,020° and 1,200°. The metal should be hardened above the latter temperature. German-silver and the alloys of copper and nickel show this peculiarity to a marked extent; when these alloys are heated their resistance decreases considerably from 570° to 930°, and in order to observe the result a specimen must be taken which has been annealed and cooled very slowly. In the case of German silver, in order to avoid almost complete hardening it is necessary to allow several hours for the cooling down from 930° to 570°. The presence of small quantities of foreign matter seems also to hinder the transformation; the amount of the change seems also to vary considerably with different specimens, and may be entirely absent, as is the case with the specimen of copper containing 20 per cent. of nickel, the resistance of which was given above. The following figures relate to three specimens chosen out of a dozen which were tested :—

—	Temperatures.						
	32°	390°	570°	750°	930°	1,290°	1,650°
Cu 50 . .	0·465	0·480	0·505	0·520	0·518	0·530	0·552
Ni 24 . .	0·495	0·513	0·527	0·525	0·518	0·530	0·552
Zn 25 . .	0·514	0·527	0·537	0·525	0·518	0·530	0·552
Cu 66 . . Ni 11 . . Zn 22 . .	0·285	0·308	0·320	0·330	0·338	0·352	0·390
Cu 81 . . Ni 18 . .	0·485	0·497	0·500	0·492	0·475	0·473	0·492

The first of these alloys gave the best marked transformation. The three series of readings were taken during the heating of specimens which had been cooled at different rates, and which were therefore hardened to different degrees.

These tests show the cause of the well-known effect that standard resistance coils of German silver do not remain constant for an

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indefinite time, and why their resistance increases. This effect arises from the fact that the wires employed are always partially hardened and gradually become annealed spontaneously from the effect of slight variations in temperature, of mechanical forces, or of the lapse of time. A similar spontaneous annealing is observable with hardened steel wires, which shows itself by a change of the resistance in an opposite direction.

The Author gives in the last Table the results obtained with specimens of alloys of iron and nickel. Some of them show different resistances in heating, and in cooling, that is to say, the changes produced by raising the temperature are not immediately reversible; the changes are only observable on the return when the temperature is at about the same as that of the surrounding air.

Percentage of Nickel.	—	Temperatures.						Transformation Points.
		32°	390°	750°	1,110°	1,470°	1,830°	
								°
5	Rising .	0·36	0·45	0·59	0·90	1·38	1·50	1,250 and 1,530
	Falling .	0·36	0·54	0·77	1·35	1·45	1·50	1,110
25	Rising .	0·98	1·15	1·30	1·42	1·51	1·55	Nil.
	Falling .	0·98	0·81	1·10	1·42	1·51	1·55	1,020
35	Rising and falling .	0·59	0·84	1·04	1·10	1·13	1·18	750
50	Rising and falling .	0·46	0·80	1·14	1·28	1·32	1·36	860

It will be seen that at temperatures above that of transformation iron, nickel and their alloys exhibit a law of change for the electrical resistance which is similar to that of platinum and its alloys, while at lower temperatures, on the contrary, the law of change is infinitely more rapid.

E. R. D.

On the Changes in Resistance of Bodies under Different Electrical Conditions. By E. Branly.

(Comptes Rendus de l'Académie des Sciences, Paris, 1891, vol. cxii., p. 90.)

The Author read a Paper before the French Academy of Sciences upon the changes in conduction of bodies under varying electrical conditions. In a certain number of tests he used as a conductor a very thin plate of copper coated in certain cases with a little tin and stretched upon a rectangular plate of unpolished glass or of ebonite of about 2·75 inches in length, and 0·78 inch in width. The resistance of this sheet of copper, which was polished with a burnisher varied from a few ohms up to several millions for the

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same weight of metal. The electrical circuit was made by means of two narrow strips of copper parallel to the short sides of the rectangular plate, and forming good contact with it by means of screws. When the two copper strips were raised the plate was cut out of the circuit. The Author also used as conductors fine metallic filings of iron, aluminium, antimony, cadmium, bismuth, &c., which he sometimes mixed with insulating liquids. The filings were placed in a tube of glass or ebonite, and were held between two metal plates. When the electrical circuit, consisting of a Daniell cell, a galvanometer of high resistance, and the metallic conductor, consisting of the ebonite plate, and the sheet of copper, or of the tube containing the filings, was completed, only a very small current flowed; but there was a sudden diminution of the resistance which was proved by a large deviation of the galvanometer needle when one or more electric discharges were produced in the neighbourhood of the circuit. In order to produce these discharges a small Wimshurst influence machine may be used, with or without a condenser, or a Ruhmkorff coil. The action of the electrical discharge diminishes as the distance increases; but the Author observed it easily, and without taking any special precautions, at a distance of several yards. By using a Wheatstone bridge, he observed this action at a distance of 20 yards, although the machine producing the sparks was working in a room separated from the galvanometer and the bridge by three large apartments, and the noise of the sparks was not audible. The changes of resistance were considerable with the conductors described. They varied, for instance, from several millions of ohms to 2000, or even to 100, from 150,000 to 500 ohms, from 50 to 35, and so on. The diminution of resistance was not momentary, and sometimes it was found to remain for twenty-four hours. Another method of making the test was, by connecting the electrodes of a capillary electrometer to the two poles of a Daniell cell with a sulphate of cadmium solution. The displacement of mercury which takes place when the cell is short-circuited, only takes place very slowly when an ebonite plate, covered with a sheet of copper of high resistance, is inserted between one of the poles of the cell, and the corresponding electrode of the electrometer; but when sparks are produced by a machine, the mercury is rapidly thrown into the capillary tube owing to the sudden diminution in the resistance of the plate. An examination of the conditions necessary to produce these results leads to the following data:—

1. The circuit need not be closed to produce the result.

After testing some plates, and having found them to be of high resistance, the Author lifted the copper contact strips and thus insulated the plates completely during the time when the sparks passed; when the strips had been replaced, and the circuit closed through the Daniell cell and the galvanometer, it was seen that the effect had been produced although the diminution of resistance is more marked if the plate, while on open circuit, is still fastened to the conductors.

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2. The passage of an induced current in the body produces a similar effect to that of a spark at a distance. The Author then describes some of the apparatus used.

3. An induction-coil with two equal lengths of wire was used, a current is sent through the primary while the secondary forms part of a circuit containing the tube with filings and a galvanometer. Before closing the circuit a test is made to see that the current at make and break gives the same deviation on the galvanometer. The filings are then placed in the secondary circuit, and the primary opened and closed at regular intervals. The following Table shows how the two induced currents caused the resistance of the filings to vary:—

Zinc filings	1st	closing,	1	1st	opening,	18
„	2nd	„	64	2nd	„	100
„	3rd	„	146	3rd	„	140
Aluminium filings . . .	1st	„	1	1st	„	5
„ „ . . .	2nd	„	40	2nd	„	47
„ „ . . .	3rd	„	59	3rd	„	81

These deviations were obtained with an induction coil without core. The results obtained with a core were almost identical.

4. When working with continuous currents the passage of a strong current lowers the resistance of the body for feeble currents. A circuit was used consisting of a battery, the body to be tested, and a galvanometer; the electromotive force of the battery used was 1 volt at first, then 100 volts, and then again 1 volt. The deviations of the galvanometer-needle for the currents produced by the electromotive force of 1 volt before and after the passage of the current produced by 100 volts, was as follows:—

	Before Passage.	After Passage.
1st plate of ebonite coated with copper	16	100
2nd „ „ „	0	15
Iron filings	1	500

Summing up, the Author states that in all these tests the use of ebonite plates covered with copper or mixtures of copper and tin was less satisfactory than the use of filings; with the plates he was unable to obtain the initial resistance of the body after the action of the spark or of the current, while with the tubes and filings the resistance could be brought back to its normal value by striking a few sharp blows on the support of the tube.

E. R. D.

A Simple Method of Dynamo-Design. By THORBURN REID.

(Electrical Engineer, New York, vol. xi., 1891, pp. 134, 160.)

The Author discusses first the formulas given by Kapp, and objects to them because in bringing in the constants required for

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the practical evolution of the design, the form of the equation is changed from the simple relation between the "magneto-motive" force, and the magnetic resistance of the three component parts of the magnetic circuit (magnets, armature and air-space) into one in which this ratio is lost, and the engineer consequently works without a sufficiently intelligent grasp as to effect of each portion of his design.

The method advocated is as follows:—The saturation-curve of the cast- and wrought-iron employed in the manufacture is first obtained, either by furnishing samples to an electrical laboratory or by the engineer himself; and here the remark is made, that the iron from any given manufacturer is sufficiently constant in its magnetic qualities to allow of one set of curves being adopted for that. These curves, with that for air (for copper is stated to be practically the same), being plotted to a suitable scale, and in the units adopted for the mechanical execution of the design, serve to determine the number of ampere turns required for exciting the magnetic field; a specimen set of such curves is inserted in the Paper. Given, then, the length and cross-section of each of the three component parts of the magnetic circuit, and assuming a leakage coefficient for the magnetic lines (dependent on the form of the magnet, and for a horse-shoe usually about 1·3), the total number of lines per unit of area required to produce the electromotive force are given, and entering the curves with this quantity, the whole process of determining the number of ampere turns required for each portion of the magnetic circuit is fully detailed. This method is applied to the calculation of these quantities for an Edison-Hopkinson machine, of which details were published in the London *Electrician* for 1886, p. 39, and the difference between the actual values and the calculated is only three per cent.

F. J.

Accumulators in Central Stations. By HERMANN MUELLER.

(Elektrotechnische Zeitschrift, 1891, p. 2.)

In this article the Author describes in detail and illustrates by diagrams various methods for using accumulators in connection with direct current dynamos in Central Electric-Light Stations. The first station equipped according to the Author's method was Barmen in 1887. The battery is placed in parallel with the dynamo, and is provided with a charging and a discharging switch so that by suitably manipulating these switches the dynamo current can be utilized partly for charging the battery and partly for direct lighting as long as the demand for current is small. At maximum demand the dynamo current is supplemented by the battery current. The Author next describes a modification of his method arranged for the three-wire system with two batteries and

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two dynamos, and finally another modification with only one dynamo (or group of dynamos coupled parallel) and two sets of batteries feeding a three-wire net-work. Special switches are employed by means of which the pressure at the station end of the feeders can be independently regulated in order to keep the pressure at the feeding points uniform throughout the district.

G. K.

Efficiency of the Transformer.

By CALVIN HUMPHREY and W. H. POWELL.

(Transactions of the American Institute of Electrical Engineers, 1890, p. 311.)

The Authors describe experiments made on a forty-light transformer, the method adopted being similar to that which was used by Prof. Ryan and Mr. Merritt in their investigation of a ten-light transformer submitted to the Institute in December of the previous year. The instantaneous values of current and electromotive force were obtained by a commutating device fixed to the spindle of the alternator. This consisted of a wooden disk with a contact pin at the periphery revolving with the shaft, and a second wooden disk, having a contact brush which could be set in different positions so as to collect the electromotive force existing at any instant. The electromotive force was measured on a quadrant electrometer to which a condenser was connected. Current measurements were made by the same apparatus by determining the potential difference between two points of a non-inductive resistance. The Authors give numerous diagrams showing the actual shape of current and electromotive force curves, and a diagram showing an efficiency curve computed from these curves. The efficiency at normal load is 96·2 per cent., and the "all-day efficiency" is 90 per cent.

G. K.

The Cost of Electric Street-Mains. By Dr. GUSTAV RASCH.

(Elektrotechnische Zeitschrift, 1890, p. 658.)

The Author bases his calculation on the formula: cost of cable $= a\,V + b\,L$, in which a and b are constants depending upon the price of copper, and the price and quality of the insulating material, whilst V represents the volume of the cable, and L its length. By means of this formula he obtains approximate estimates for the various arrangements of feeders and mains which may be adopted in any given case of distribution, the mains being calculated for an equal maximum drop in pressure, and the feeders for equal energy loss. Comparing first the three-wire with the

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two-wire system, he finds that the total volume of copper in the former is 60 per cent. of the latter, whilst the length is 150 per cent. This refers to the mains, whilst in the feeders the volume is 27·6 per cent. of an equivalent two-wire feeder and the length 150 per cent., there being three wires instead of two. The differential current in the middle wire is assumed not to exceed 10 per cent. of the total current. For the four-wire system the Author finds the following figures of comparison with an equivalent two-wire system. Mains: volume, 46·6 per cent.; length, 200 per cent. Feeders: volume, 16 per cent.; length, 200 per cent. Similarly for the five-wire system. Mains: volume, 40 per cent.; length, 250 per cent. Feeders: volume, 9·4 per cent.; length, 250 per cent. A practical example is given to explain the application of these figures. The Author assumes that the feeders and mains for a certain area of distribution have been formed on the two-wire system. The question to be solved is how far can the total cost be reduced by adopting a multiple-wire system. The figures for the two-wire system are:—

Volume of mains, 1,500,000 cubic centimetres; length, 5,000 metres.
„ feeders, 1,600,000 „ „ „ 10,000 „

The cost of the various systems is then found to be as follows:—

System.	Two.	Three.	Four.	Five wires.
Cost in £	5,775	3,695	3,685	3,935

In conclusion the Author points out that his method does not pretend to be more than a rough approximation to be used in working out preliminary estimates.

G. K.

The Verona Electric-Light Station. By Walter Meng.

(Elektrotechnische Zeitschrift, 1891, p. 25.)

This station has been at work since last September, and, although unimportant as regards total capacity, the Author considers it interesting enough for description on account of certain details. The boilers and engines are of Italian make, the dynamos of German make. The engines are vertical compound tandem engines developing each 85 HP. at 265 revolutions per minute; each engine drives by belts two dynamos which feed a three-wire net-work. The belt speed is 4,500 feet per minute, or considerably more than customary, but the Author states that no difficulty has arisen from the high belt-speed. The distributing system is overhead, and the streets being too narrow to admit of the erection of posts, the wires are carried by iron brackets fastened to the houses at a height between the first- and second-floor windows.

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The average length of each feeder is 4,000 feet and the average current in each feeder is 350 amperes. The wires are naked, and no stouter wire than 275 mils diameter has been used, as it was found impossible to properly strain heavier wire. The total length of net-work is about 26,000 feet and the total length of single wire erected is 380,000 feet. All junctions are made by means of fuse boxes. The cost of the street-mains amounted to 30*s.* per 16 candle-power lamp.

G. K.

Comparative Tests of an Electric Motor and a Steam-Locomotive. By LINCOLN MOSS.

(Transactions of the American Society of Civil Engineers, vol. xxiii., 1890, p. 193.)

The tests described in this paper were made on the Manhattan Elevated Railway, New York, in February, 1889, on a section of road 1·76 mile long. The trial trains were made up of the electric or steam locomotive and empty cars, each weighing 29,500 lbs. At first two cars were attached, then three, and finally four. The generating-station for the electric service contained a steam-engine capable of developing 400 I. HP. and four 50 HP. dynamos; but the Author does not state the current or voltage. The positive conductor along the railway consisted of $\frac{5}{8}$ in. diameter, copper rods, bolted to the wooden guard timbers by insulated clamps. The insulation resistance is not given. The return circuit was through the rails. The motor was connected by steel spur-wheels with the rear axle, and the latter was geared with the front axle by coupling rods. The wheels were 48 in. diameter, and the maximum pull exerted by the electro-motor at the moment of starting was 4,500 lbs. The weight of the locomotive exceeded 10 tons. A Shaw hydraulic dynamometer was used to determine the pull on the draw-bar.

Diagrams are given, showing the profile of the line and the HP. exerted on the train, and indicated in the engine at the same moment. Indicator-cards were taken throughout the run at intervals of 16 seconds, and the nett HP. transmitted to the train was determined from the observed speed and pull on the draw-bar. The indicated power averaged 176·8 I. HP., and the average nett train-power 26·7 HP., making the average efficiency 15 per cent. Speed about 10 miles per hour. When a steam-locomotive was used, the average indicated power was 25·92 I. HP., and the average net train-HP. was 21·95 HP., making the efficiency 85 per cent. The speed was slightly lower.

The Author concludes the paper by a comparison of the working expenses of the two cases, and finds that electric propulsion, at the moderate speed of 9 or 10 miles per hour would cost 2·38, and at 15 miles per hour four times as much as haulage by steam-locomotives.

G. K.

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The Heating of Naked Copper Wires by a Current.

By U. Barbieri.

(Elektrotechnishe Zeitschrift, 1891, p. 30.)

The Author gives an account of experiments carried out in the Munich Electrical Laboratory to determine the coefficient in the temperature formula c^2/r^3 (c being the current and r the radius of the wire) for copper wires of 20, 40, 60 and 80 mils diameter. A piece of the wire to be tested was firmly attached to the wall of the room at one of its ends, and the other end was led over a pulley and strained with a suspended weight of about one-tenth the breaking stress. A mirror fastened to the pulley in conjunction with a scale and telescope permitted an exact determination of the elongation of the wire when heated by a current, and the temperature was calculated from the observed elongation. The Author finds that the coefficient depends on the size of the wire and also to a certain extent on the current, but taking averages as regards the latter variations the following Table gives the coefficient for the different wires.

Diameter of wire in mils . . .	20	40	60	80
Coefficient	0·018	0·024	0·030	0·036

The highest temperature reached in these experiments corresponded to a rise of 200° Centigrade over the temperature of the room.

G. K.

The Electrical Resistance of Gases in the Magnetic Field.

By A. Witz.

(Journal de Physique, 1891, vol. x. p. 68.)

If a tube provided with suitable terminals and filled with a gas be placed in a magnetic field, the potential between its terminals, when excited by a Ruhmkorff coil, increases with the intensity of the field. The term resistance, as applied to such a tube, is hardly correct, as there is no fixed relation, as in ordinary conductors, between current and electromotive force, and the Author therefore gives in each series of experiments the value of electromotive force and current observed, the former by a spark micrometer, and the latter by a special galvanometer. The portion of the tube subjected to the magnetic field, is of considerable influence on this effect, but this again varies with the nature of the gas. Thus for air the maximum occurs opposite the negative pole, and is greater there than at the positive pole;

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while for bromine, chlorine, etc., it is just the opposite. If the line of magnetic force traverses the tube parallel to the length, the effect is almost nil. The effect also varies considerably with the pressure of the gas, thus at a pressure of three atmospheres the alteration in resistance is very small, while at a pressure of about $\frac{1}{100}$ of an atmosphere the resistance increased tenfold, showing that the magnetic field acts on the electric stream and not on the spark. The effect is ascribed to the change in the capacity, which modifies the state of vibration of the gaseous particles.

F. J.

The Petroleum and Inflammable Gas of the Trenton Limestone in Ohio and Indiana. By Edward Orton.

(Eighth Annual Report U.S. Geological Survey, Part II., 1890, p. 483.)

In certain districts of Ohio and Indiana the Trenton limestone has been recently found to be one of the most important sources of petroleum and gas in the United States. The principal centres of development are, in Ohio, at Findlay, about 45 miles south of Toledo on Lake Erie, Lima, and Saint Mary's, near the western boundary of the State, and in Indiana, a district about 60 miles by 40 of an area of about 1,800 square miles, the centre of which is about 60 miles N.W. of Indianapolis. In both States the geological conditions are similar, the gas-field being limited to a high-lying area of the Trenton limestone which is nearly flat, forming a subterranean terrace about 300 to 350 feet below the sea-level, covering the districts in which the same limestone is at greater depth, being unproductive for gas though sometimes producing oil. The surface, which has a maximum elevation of about 400 feet above Lake Erie at a distance of 60 or 80 miles from it, is deeply covered with drift deposits, and the drainage being sluggish, swampy and marshy areas abound. The district was in early times known as the Black Swamp. At Findlay, where the gas has been most largely developed, about twenty wells were active in 1885, but of variable yield, some of the smaller ones falling below 200,000 cubic feet a day, while at the other end of the scale the Karg well, when measured in May, 1885, delivered from a 4-inch pipe a little more than 12,000,000 cubic feet per day, the volume being computed at 50° Fahrenheit. Similar measures made on five other wells showed a daily production from 1,159,000 to 3,318,000 from 2-inch pipes. The depth of the wells varies from about 1,000 to 1,100 feet from the surface, and the maximum or rock pressure when the gas is shut within the well is from 300 to 400 lbs. per square inch, or only about half of that observed in the great gas-wells of Pennsylvania, where from 750 to 950 lbs. has been observed. The open pressure, or that registered on a gauge held on the current of

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escaping gas from a pipe of any size, is considerably less. The highest pressure noted in the casing pipe, $5\frac{5}{8}$ inch diameter, of any Ohio well is $6\frac{1}{2}$ lbs. per square inch; but this is rapidly increased when the area of the well is contracted. A well that gives 6 lbs. in the casing shows $20\frac{1}{2}$ lbs. when the gas is made to escape through a 4-inch pipe. The methods of determining the volume of gas escaping from a high-pressure well are due to Professor S. W. Robinson, who undertook his investigations for the Ohio Geological Survey, and worked them out upon the great wells of Findlay, and especially on the strongest of all, namely the Karg well. These methods are very simple and easy of application, the strongest of gas-wells, provided the gas is dry, can be measured by a single observation that need not occupy more than a few seconds. The appliance adopted where the pressure is moderate is the Pitot tube, the pressure being read in inches of water or mercury, and the velocity in feet per second found by the expression—

$$v = 83{\cdot}1\sqrt{h},$$

h being the height of the water column in inches. The daily discharge is—

$$V = 86400\ v\ a,$$

a being the area of the delivery-pipe in superficial feet.

In the larger wells a steam-gauge is used to read the pressure, and the velocity is computed by the formula for adiabatic flow where a gas flows from a receiver into a space outside with a relatively large fall of pressure. The mathematical discussion of the problem is given at length in Vol. vi. of the "Reports of the Geological Survey of Ohio," but not reproduced in the present Report. The numerical results are however exhibited in tables, in which the volumes are given for wells from 11·6 inches diameter for pressures from 0·1 inch of water to 60 lbs. per square inch. Where the flow is less than 1,000,000 cubic feet per day the velocity may be directly determined by an anemometer.

The gas from the different wells is remarkably uniform in composition in both States, the analysis varying between the following limits—

—	Minimum Per cent.	Maximum Per cent.
Hydrogen	1·2	2·35
Marsh gas	92·67	94·16
Oleflant gas	0·15	0·49
Carbonic oxide	0·41	0·73
Carbonic acid	0·20	0·30
Oxygen	0·30	0·40
Nitrogen	2·80	3·82
Sulphuretted hydrogen	0·15	0·21

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Although employed both for lighting and heating, the chief value of this gas is for the latter purpose. Theoretically about 31,000 cubic feet are equal in calorific power to 1 ton of Pittsburg coal, but practically less than half this amount of gas will do the work done by 1 ton of coal. The chief drawback is in the sulphur compounds contained, which renders the gas offensive when diffused. This, however, is not an uncompensated disadvantage, as even the smallest leakage is immediately disclosed by the smell, and thus dangerous accumulations may to some extent be guarded against. The chief use is, however, in raising steam and in heating for iron and steel manufacture. At the Briggs Tool-works in Findlay the gas was first used for welding iron and steel in June, 1886, doubt having been previously felt as to the practicability of this application owing to the sulphur contained in the gas, but it has proved thoroughly adequate to the service.

A more important application of the gas is, however, in the manufacture of glass, for which it is so completely adapted that a great advantage is given to localities where it can be commanded. The principal seats of glass manufacture in Ohio are at Wheeling and Bellaire, and large sums have been expended in the search for gas near those places but without result. It is therefore either brought by pipe-lines to the works, or the latter are bodily transferred to the gas-fields. The first glass-works in Findlay was built by a Bellaire firm in 1886, and the fuel bill for the same scale of operations, which would have been £60 per month in the old location, was reduced to £40 per annum. Since that date six other glass-works, as well as three rolling mills, have been established.

In the Indiana gas-fields the conditions observed are similar to those prevailing in the Findlay district, the upper surface of the productive gas-rock lying from 65 feet above to 90 feet below the sea-level, or from 875 to 975 feet below the surface of the ground. When the rock is more than 100 feet below the sea-level the bore-holes almost invariably yield salt water. The essential condition for gas-production is that the rock should be porous, and this is only realized in those districts where the Trenton limestone, which is over the greater part of its area, is compact, and nearly pure carbonate of lime is converted into a dolomite, the change being accompanied by the development of a crystalline structure with large interstitial spaces. In the most productive wells the proportion of carbonate of magnesia in the rock varies from 37 to 43 per cent., and that of carbonate of lime from 52 to 56 per cent., while in the dry wells the former constituent is sometimes as little as 1 per cent., or even entirely absent, the well being a nearly pure limestone. In this cellular rock the gas and oil accumulates in the higher parts of the slightly undulating surface of the rock, these lighter substances being imprisoned by the pressure of salt-water in the lower portions of the bed. It is noticeable that this brine contains

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a much larger proportion of calcium and magnesium chlorides than sea-water, and therefore that it represents an ancient bittern, or mother liquor remaining after the separation of salt by atmospheric evaporation.

A large number of wells have been drilled in the field in Indiana, the most important one being at Fairmont, which yielded 11,500,000 cubic feet in June, 1887; several others yielded from 1,000,000 to 5,000,000, and at a few points larger ones from 5,000,000 to 11,000,000 feet have been struck. The supply has been far in excess of any considerable demand, as the district is mainly an agricultural one, and the discoveries have led to sharp competition between the localities, most of the towns offering land for building free of charge, and also free fuel for the purpose of attracting population, and, in the words of the Author, a vandal-like waste has characterized the early exploitation of most of the subdivisions of the field. Numerous industries, including especially glass manufactories and rolling-mills, are, however, being brought into the more promising of the towns, and a rapid and substantial growth is going forward in many of them.

The Lima Oil-field.[1]—This district, which the Author considers to be second only in productive power to the great Russian oil-field on the Caspian, is situated midway between the Indiana and Ohio gas-fields. As far as proved at present it consists of a tract 8 or 10 miles long and from 2 or 3 miles broad. The surface elevation averages from 850 to 900 feet, and the productive area is limited to a flat-lying terrace of Trenton limestone, between 375 and 390 feet below the sea-level, the dead-line, where only salt-water is found, being at 400 feet. The field is a very productive one, in fact the output has been restricted owing to a difficulty in disposing of the product; the highest daily yield is not far from 14,000 barrels. In July, 1887, the price obtained was only 15 cents (7½*d.*) per barrel of 40 gallons. In the North Baltimore field single wells have yielded as much as 5,000 gallons per day, while nearly one half of the wells in operation at that period gave 100 barrels or more.

The Trenton limestone oil is of dark colour, rather low in specific gravity, 0·31 to 0·42, and containing some sulphur compounds which make it rather offensive and difficult to refine. These drawbacks make it unsuited for competition with the purer oils from Pennsylvania as an illuminating material; but it is well suited for fuel. Four barrels of oil are considered equal in heating power to 1 ton of bituminous coal, and at the present price (15 cents. per barrel) it could scarcely be displaced by natural gas. An enormous stock of power vastly greater than that of the natural gas-fields is made available in the Trenton limestone oils.

H. B.

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[1] The Lima oil is used as boiler fuel at the works of the Illinois Steel Company at South Chicago, whence it is conveyed by a pipe line 208 miles in length.—H.B.

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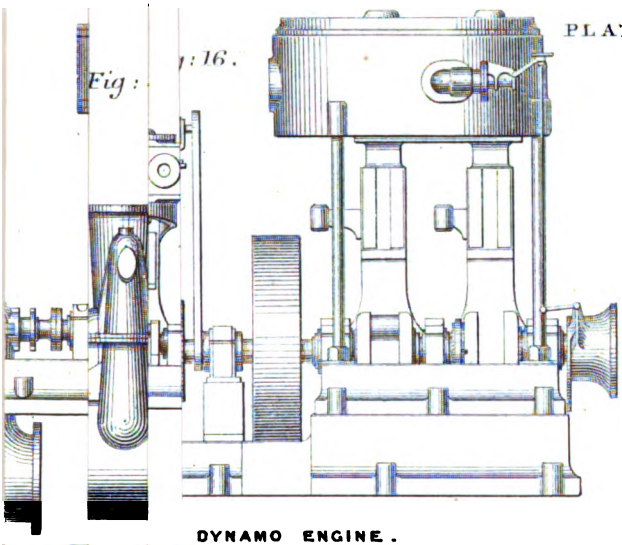
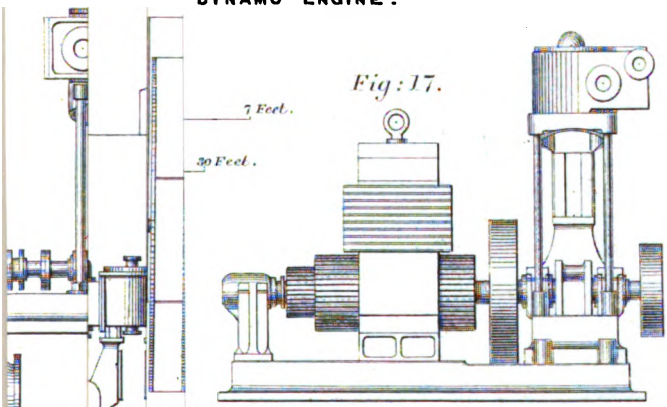
Fig: 16.



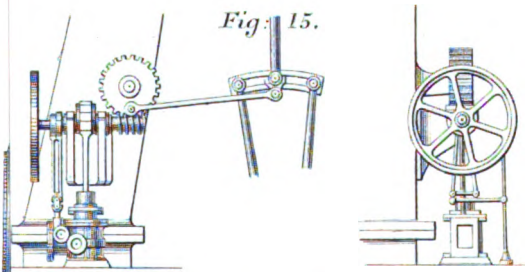
DYNAMO ENGINE.

Fig: 17.



ORDINARY PASSENGERS AND CARGO STEAMER DYNAMO ENGINE.

Fig: 15.



ROUNDABOUT REVERSING ENGINE.

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